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- WHY YOU'RE RELATED TO ROYALTY
- DUST BOWL AMERICA
- HOW FIRE TORNADOS FORM
- MAKE A BUG CATCHER

FUTURE
ISSUE 155

MEAN, GREEN MILITARY MACHINES

WHAT HAPPENS TO NUCLEAR WASTE?

WHY BRUSHING TEETH IMPROVES YOUR HEALTH

MEET THE DEEP SPACE EXPLORERS


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SPACEPORT
HIMALAYA
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SVD
FUTURE OF
SPACE VEHICLE
DEPOLOYMENT

WELCOME

Issue 155

The story of Earth

PAGE 26

"Earth was just a hot rock in a lifeless star system"

Major Tim Peake, our interviewee this issue, touches on the theme of our cover feature in this new-look issue of **How It Works**: that life in the universe is an incredibly rare phenomenon. It makes our planet, which is an oasis for a huge variety of life forms, including intelligent life, a very special place indeed. We've explored the evolution of Earth over its 4.5-billion-year history, the formation of life, landmasses and its changing atmosphere. It's an amazing story, especially when you consider the many freak cosmic accidents and flukes of nature that without which Earth might have ended up a barren rock like Mars or an otherwise completely different place today. Enjoy!

Ben Biggs
EDITOR

HIGHLIGHTS

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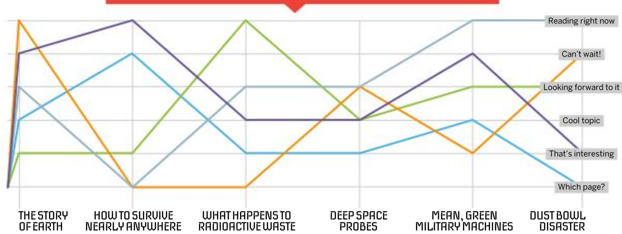
WHAT WE'RE ANTICIPATING



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INSIDE

Issue 155

66 AR

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MEET THIS ISSUE'S EXPERTS

ANDY EXTANCE
Andy is a science writer. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

DR ANDREW MAY
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

LAURA MEARS
Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

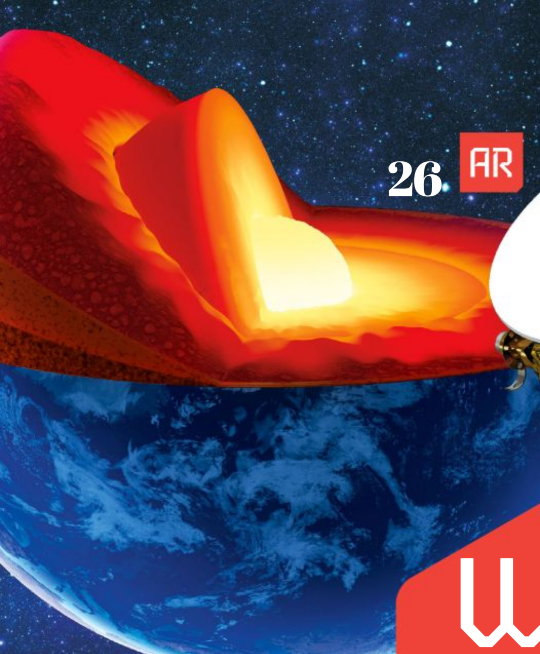
JO ELPHICK
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

CHARLOTTE HARTLEY
Charlotte works in science communication. Her main interests lie in all things biology, but particularly nature and wildlife.

MIKE JENNINGS
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

CALLUM MCKELVIE
All About History magazine's Features Editor studied history at Aberystwyth University while working for museums and archives.

MARK SMITH
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.



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PAGE 54

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Tiny deer hunter

Meet the deer ked, a skin parasite also known as *Lipoptena cervi*, which loves the taste of deer blood. Using their hooked legs, these tiny parasites latch onto their host's fur, utilising their specialised claws to cling onto individual hairs. When these insects emerge from the pupal stage they are equipped with wings, allowing them to find their first host. Upon locating and latching onto a host, they shed their wings.

© Getty

Supercell cyclone

Tornado Alley is famous for its high frequency of tornadoes and supercell thunderstorms. These intense weather systems sweep across numerous states of North America, including Texas, Kansas and Iowa. This image was taken in another Tornado Alley state, Nebraska, near the city of Broken Bow, and it shows a low-precipitation supercell mesocyclone over the Nebraskan High Plains.

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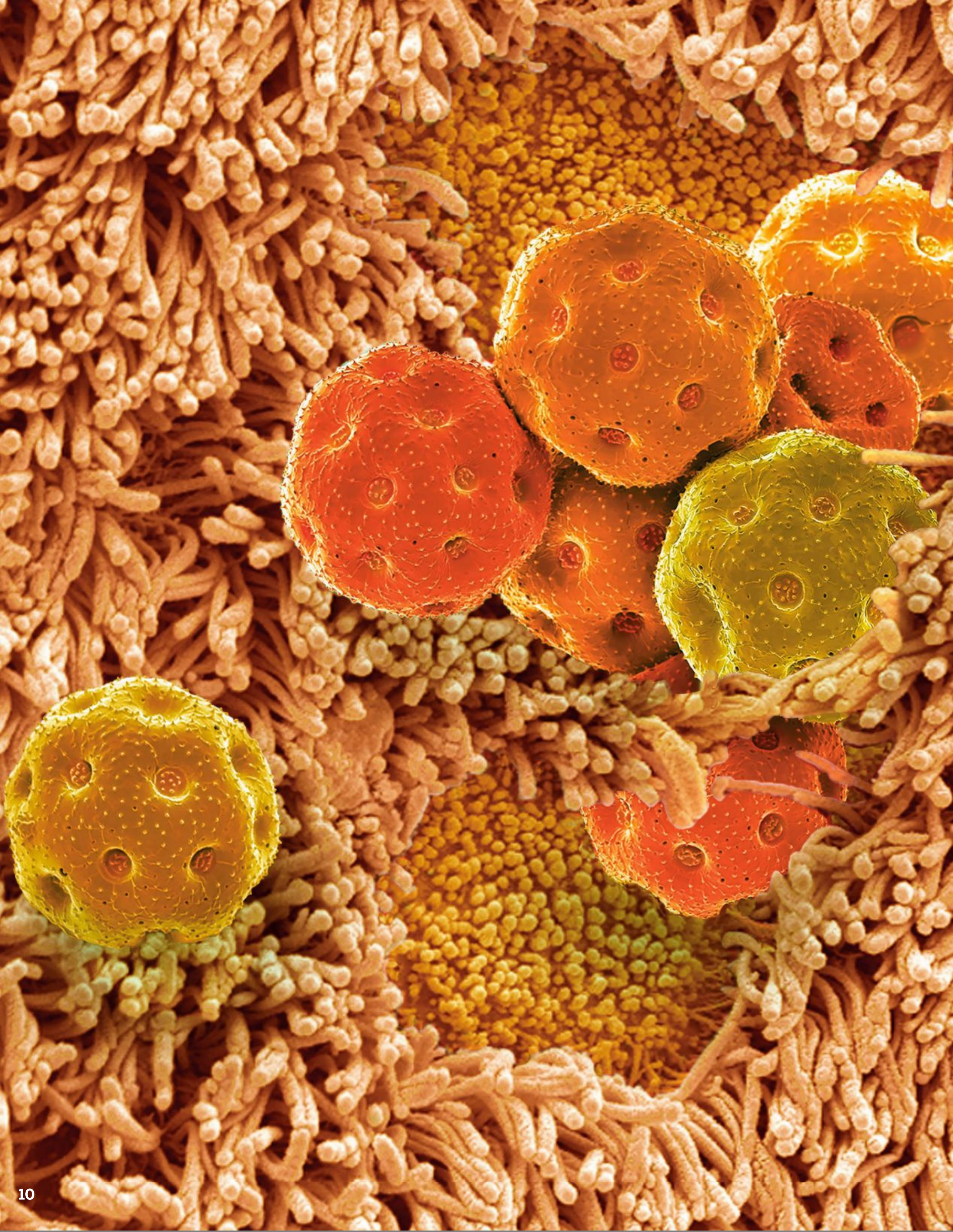


Snot science

The internal lining of the human nose is filled with countless hair-like protrusions called cilia. These tiny organelles act as a nasal conveyor belt, moving sticky mucus to the back of the nose and down into the stomach. This process is known as mucociliary clearance, and it's the human body's way of trapping harmful bacteria, viruses or allergens before they can infect the body and cause damage to it.

Titanium tantrum

11,090 light years from Earth lies the remnants of a supernova, Cassiopeia A. It's one of the youngest known, at around 350 years old. What makes Cassiopeia A special is that it's blasting out fragments of titanium. This composite image was created by NASA's Chandra X-ray Observatory, which imaged several elements: titanium (blue), iron (orange), oxygen (purple), silicon (red) and magnesium (green).

© NASA/CXC/RIKEN/T. Sato et al.; NuSTAR: NASA/NuSTAR

SPACE & PHYSICS

Light from behind a black hole spotted

WORDS BEN TURNER

Astronomers have detected light coming from behind a black hole for the first time, proving Einstein right yet again. Researchers were studying X-rays flaring from a supermassive black hole in the centre of galaxy I Zwicky 1, 800 million light years away, when they discovered the unexpected phenomenon. Alongside the expected X-ray flashes from the front of the black hole, the scientists also detected a number of 'luminous echoes' from an origin they initially couldn't place.

Stranger still, the out-of-place light bursts were smaller, arrived later and had different colours from the flares seen coming from the front of the black hole. The researchers soon realised that the echoes were arriving from behind the supermassive black hole – true to Einstein's theory of general relativity, it was warping space-time, enabling the light to travel around the black hole.

"Any light that goes into that black hole doesn't come out, so we shouldn't be able to see anything that's behind the black hole," said Dan Wilkins, a research scientist at the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University. "The reason we can see that is because that black hole is warping space, bending light and twisting magnetic fields around itself."

Einstein's theory of general relativity describes how massive objects can warp the fabric of the universe, called space-time. Gravity, Einstein discovered, isn't produced by an unseen force, but is simply our experience of space-time curving and distorting in the presence of matter and energy. This curved space sets the rules for how energy and matter move. Even though light travels in a straight line, light travelling through a highly curved region of space-time, like the space around a black hole, will also travel in a curve, in this instance from its back to its front. This isn't the first time that astronomers have spotted a black hole distorting light, called gravitational lensing, but it is the first time that they've seen light echoes from the area behind a black hole.

The astronomers didn't intend to confirm Einstein's theory, formulated more than 100 years ago in 1915. Instead they hoped to use the European Space Agency's XMM-Newton and NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) to peer at the light emitted from the cloud of super-hot particles that forms just outside of the black hole's point of no return, or event horizon.

The super-hot cloud, or corona, wraps around the black hole and gets heated up as it falls in. Temperatures in the corona can reach millions of degrees, turning the cloud of particles into a magnetised plasma as electrons are ripped from atoms. The spinning of the black hole causes the combined magnetic field of the coronal plasma to arc high above the black hole and eventually snap, releasing X-rays from the corona as a result.

"This magnetic field getting tied up and then snapping close to the black hole heats everything around it and produces these high-energy electrons that then go on to produce the X-rays," Wilkins said. Now that the researchers have made this observation, their next steps will be to study in more detail how light bends around black holes and investigate the ways black hole coronas create such bright X-ray flashes.

Positive results for plague in chipmunks prompted officials to close several spots in the vicinity

ANIMALS

CALIFORNIA CHIPMUNKS CONTRACT THE PLAGUE

WORDS RACHAEL RETTNER

Chipmunks in the South Lake Tahoe area in California have tested positive for plague. Officials announced Kiva Beach and the Taylor Creek Visitor Center in South Lake Tahoe closed following the positive plague tests. It's believed that the infected chipmunks had no known contact with people.

The bacterium that causes plague, *Yersinia pestis*, is naturally present in some parts of California, including in El Dorado County where South Lake Tahoe is located. Last year, a resident of South Lake Tahoe tested positive for plague, marking the first case in the state in five years.

Plague is best known for causing the Black Death in Europe in the 1300s. Infections still occur in modern times, although human cases are relatively rare and usually treatable with common antibiotics. In the US, about seven cases of plague occur each year on average. Most plague cases occur in northern New Mexico, northern Arizona, southern Colorado, California, southern Oregon and far-western Nevada. Worldwide, most human cases since the 1990s have occurred in Africa. The disease is spread by rodents, including squirrels, rats and chipmunks, and their fleas. Humans can catch the plague through flea bites or contact with the tissues or bodily fluids of an infected animal.

PLANET EARTH

Ignoring climate change will yield "untold suffering"

WORDS BRANDON SPECKTOR

Nearly 14,000 scientists have signed a new climate emergency paper, warning that "untold suffering" awaits the human race if we don't start tackling global warming head-on, effective immediately. The new paper is an update of a 2019 paper that declared a global climate emergency and evaluated Earth's vital signs based on 31 variables, including greenhouse gas emissions, surface temperature changes, glacial ice mass loss and Amazon rainforest loss, plus various social factors like global gross domestic product (GDP) and fossil fuel subsidies.

Greenhouse gas emissions are at an all-time high, while glacial ice thickness is at its lowest point in 71 years of record-keeping. The world is richer than it's ever been, measured by global GDP, while the sky is more polluted than ever, measured by carbon dioxide, methane and nitrous oxide concentrations in the atmosphere.

"The updated planetary vital signs we present reflect the consequences of unrelenting business as usual," the authors wrote in the study. "A major lesson from COVID-19 is that even colossally decreased transportation and consumption are not nearly enough, and that instead transformational system changes are required, and they must rise above politics."

Did you know?
China emits 27 per cent of world emissions

While the report includes some positive trends, like record increases in the use of solar and wind energy and institutions divesting money from the fossil fuel industry, it paints a generally bleak picture of the future, accentuated by ongoing surges in climate-related disasters like floods, hurricanes, wildfires and heat waves. The planet may also be about to pass – or has already passed – critical natural tipping points, such as the Amazon rainforest becoming a carbon source rather than a carbon sink, from which it will be hard to recover.

This all boils down to one conclusion – the future habitability of our planet depends on immediate large-scale action. To accomplish this task, the team suggests a three-pronged near-term policy approach: implement a "significant" global carbon price to reduce emissions, phase out and eventually ban fossil fuels and restore and protect key carbon-rich ecosystems, like forests and wetlands, to preserve the planet's largest carbon sinks and protect biodiversity.

The International Space Station flies over a city at night. Human activity may be pushing the climate beyond a 'tipping point'

© Getty / XXXX

HISTORY

Just 1.5 per cent of our genome is 'uniquely human'

WORDS RACHAEL RETTNER

Less than ten per cent of your genome is unique to modern humans, with the rest being shared with ancient human relatives such as Neanderthals. Researchers also found that the portion of DNA that's unique to modern humans is enriched for genes involved with brain development and brain function. This finding suggests that genes for brain development and function are what really set us apart genetically from our ancestors. However, it's unclear what this finding means in terms of the actual biological differences between humans and Neanderthals. "That is a giant question that future work will have to disentangle," says Richard E. Green, an associate professor of biomolecular engineering at the University of California. "At least now we know where to look."

Researchers aimed to tease apart the genes that are unique to modern-day humans as opposed to inherited from ancient ancestors. But this process is tricky because humans have genetic variants they share with Neanderthals, not only because the two groups interbred, but also because humans and Neanderthals inherited some of the same genetic variants from a common ancestor.

The researchers developed an algorithm, known as the 'speedy ancestral recombination graph estimator', which enabled them to more efficiently tell the difference between parts of the genome modern humans inherited due to interbreeding with Neanderthals and parts that humans shared with Neanderthals prior to the evolutionary split between Neanderthals and humans roughly 500,000 years ago.

They used the algorithm to analyse 279 modern human genomes, two Neanderthal genomes and one genome from Denisovans, another group of archaic humans. They found that just one-and-a-half to seven per cent of the human genome is unique to *Homo sapiens*, free from signs of interbreeding or ancestral variants. Green described the seven per cent value as the portion of the human genome where humans are more closely related to each other than to Neanderthals or Denisovans. The 1.5 per cent value is the portion that includes gene variants that all humans have, but no Neanderthal or Denisovan had.

"It seems like not a lot of the genome is uniquely human," Green said. Researchers were also surprised that most of the genes within that portion were "genes that we know and recognise," largely coding for proteins known to be involved in brain development and function rather than genetic material that isn't known to have a specific function.

PLANET EARTH

THE AMAZON CREATES MORE GREENHOUSE GASES THAN IT ABSORBS

WORDS BRANDON SPECKTOR

Forests absorb carbon dioxide (CO_2) from Earth's atmosphere, making them a key part of mitigating climate change. But humans may have already rendered the world's largest rainforest useless in the battle against greenhouse gases. The Amazon is now emitting more than 1 billion tonnes of CO_2 a year, meaning the forest is releasing more carbon into the atmosphere than it's removing.

The carbon balance tipped due to "large-scale human disturbances" in the Amazon ecosystem, researchers wrote in a study, with wildfires – many deliberately set to clear land for agriculture and industry – responsible for most of the CO_2 emissions from the region. These fires also reinforce a feedback loop of warming, the team found, with more greenhouse gases contributing to longer, hotter dry seasons in the Amazon, which lead to more fires and more CO_2 pollution.

The eastern Amazon in particular, which has seen historically greater amounts of deforestation over the past 40 years, has become hotter, drier and more prone to fires than the rest of the rainforest. The result is greater amounts of greenhouse gas emissions from the region and fewer trees to suck up the carbon again through photosynthesis.

Wildfires in the Amazon are polluting the air with greenhouse gases faster than the surviving trees can absorb it

HISTORY

Megaripples from dinosaur-killing asteroid are under Louisiana

WORDS LAURA GEGGEL

Ancient 'megaripples' as tall as five-storey buildings are hiding deep under Louisiana, and their unique geology indicates that they formed in the immediate aftermath of the asteroid strike that killed the non-avian dinosaurs.

The 16-metre megaripples are about 1,500 metres under the Lake Iatt area and date to the end of the Cretaceous period 66 million years ago, when that part of the state was underwater. The megaripples' size and orientation suggest that they formed after the giant space rock, known as the Chicxulub impactor, slammed into the Yucatán Peninsula. This led to the Chicxulub impact tsunami, whose waves then rushed into shallower waters, creating the megaripple marks on the seafloor. The occurrence of "ripples of that size means something very big had to disturb the water column," said Gary Kinsland, a professor in the School of Geosciences at the University of Louisiana at Lafayette. "This is just further evidence that the Chicxulub impact ended the Cretaceous period."

The project began when the energy corporation Devon Energy took a 3D seismic survey of Lake Iatt. A seismic survey entails creating loud sound waves and placing surface detectors around the area that can capture the returning sound waves, which are reflected when they hit various underground rock layers. Data from these sound waves allows researchers to make maps of the underground geology. Researchers took the Devon Energy data and created a seismic image of the subterranean area. When Kinsland looked at the seismic image, "I immediately saw the ripples, and I knew the direction the water would have had to have been travelling [to create them]," he said. "I knew that if you go backwards from that, you run right into Chicxulub."

Kinsland was able to determine the tsunami's direction because the megaripples are asymmetrical, which shows the direction the water was flowing when they were made. In this case, the long asymmetrical side of the megaripples have a south-southeast-facing slope, which points back to the Chicxulub impact crater.

The megaripples have an average wavelength (from one crest to the next) of 600 metres. That, combined with their almost 16-metre-high amplitude, makes them "the largest ripples documented on Earth," the researchers wrote. Moreover, these megaripples are at the top of the Cretaceous-Paleogene geological boundary dating to 66 million years ago, and lie beneath a layer of debris that was kicked up in the aftermath of the Chicxulub impact.

More evidence has been discovered to denote the dinosaurs' demise

© Getty

PLANET EARTH

'Massive melting event' strikes Greenland

WORDS BEN TURNER

Since 27 July, roughly 8.5 billion tonnes of ice has been lost per day from the surface of the enormous ice sheet – twice its normal average rate of loss during summer. The huge loss comes after temperatures in north Greenland soared to above 20 degrees Celsius, which is double the summer average.

High temperatures on 28 July caused the third-largest single-day loss of ice in Greenland since 1950 – the second and first-biggest single-day losses occurred in 2012 and 2019. Greenland's yearly ice loss began in 1990. In recent years it has accelerated to roughly four times the levels before 2000.

Even though the amount of ice that melted in this summer's event was less than two years ago, in some ways it could be worse. "While not as extreme as in 2019 in terms of gigatonnes, the area over which melting takes place is a bit larger than two years ago," researchers wrote. Global sea levels would rise by about six metres if all of Greenland's ice melted.

Xavier Fettweis, a climate scientist at the University of Liège, Belgium, estimated that around 22 billion tonnes of ice melted from Greenland's ice sheet on 28 July, with 12 billion tonnes making its way into the ocean. He tweeted that the other 10 billion tonnes of melted ice was reabsorbed "by the snowpack thanks to the recent heavy snowfall".

Fettweis attributes the cause of the acceleration in the day's melting to an atmospheric event, an anticyclone, above the continent. Anticyclones are regions of high pressure which enable the air contained within them to sink, warming as it does so in the summer and creating conditions where hot weather can persist in one area for a long time.

Greenland's melting season typically runs from June to early September. This year's melting season has already seen more than 100 billion tonnes of ice melt into the ocean. Greenland's ice sheet is the only permanent ice sheet on Earth besides the one in Antarctica and has an area of roughly 650,000 square miles.

Did you know?
Greenland has about 56,000 inhabitants

Ice receding from a glacier near Kangerlussuaq, Greenland. This photo was taken during a helicopter tour of the region with US secretary of state Antony Blinken in May 2021

HEALTH

US LIFE EXPECTANCY HAD A HUGE DECLINE IN 2020

WORDS RACHAEL RETTNER

US life expectancy dropped 1.5 years in 2020 – the largest decline since World War II – as a result of the high death toll from the COVID-19 pandemic, according to a report from the Centers for Disease Control and Prevention (CDC).

The report, which is based on preliminary death data for all of last year, estimated that US life expectancy fell from 78.8 years in 2019 to 77.3 years in 2020. That's the biggest decline in life expectancy in nearly 80 years, since 1942 to 1943, when life expectancy fell 2.9 years. The drop also brings life expectancy down to the lowest level since 2003.

About three-quarters of 2020's decline in life expectancy can be attributed to deaths from COVID-19, while 11 per cent of the decline is due to increases in accidental deaths, including drug overdoses. A record 93,000 drug overdose deaths occurred in 2020, which is a 30 per cent increase compared with 2019.

The decline in life expectancy was greater for men than women: men saw a 1.8-year drop in life expectancy in 2020, compared with 1.2 years for women. Life expectancy at birth is an estimate of how long a population of people would live if they were to experience the death rates seen in a given period. Life expectancy in the US rarely declines, and even seemingly small drops make headlines.

Memorials hang at Greenwood Cemetery to remember and celebrate the lives of those killed in the COVID-19 pandemic

SPACE

Water vapour detected on Jupiter's massive moon

WORDS CHARLES Q. CHOI

In the wisp-thin sky of Ganymede, the largest satellite in the Solar System, astronomers have detected evidence of water vapour for the first time. The discovery could shed light on similar watery atmospheres that may envelop other icy bodies in the Solar System and beyond.

Previous research suggested that Ganymede – which is larger than Mercury and Pluto and only slightly smaller than Mars – may contain more water than all of Earth's oceans. However, the Jovian moon is so cold that water on its surface is frozen. Any liquid water would lurk about 100 miles below its crust.

Prior work suggested that ice on Ganymede's surface could turn from a solid directly to a gas, skipping a liquid form entirely, so that water vapour could form part of the giant moon's thin atmosphere. However, evidence of this water has proved elusive... until now.

In a new study, researchers analysed old and new data of Ganymede from NASA's Hubble Space Telescope. In 1998 Hubble captured the first ultraviolet images of Ganymede, including pictures of its aurorae, the giant moon's versions of Earth's northern and southern lights. Colourful ribbons of electrified gas within these aurorae helped provide evidence that Ganymede has a weak magnetic field.

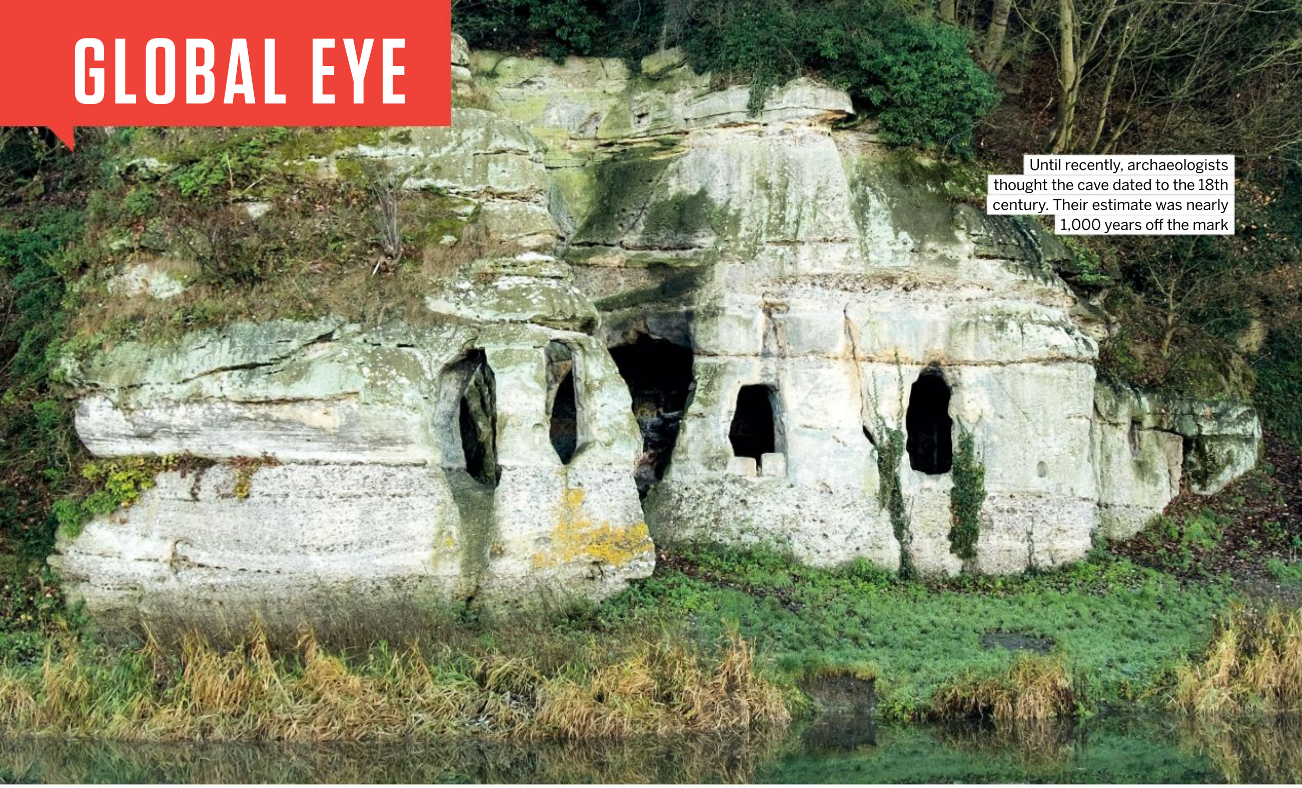
Ultraviolet signals detected in these auroral bands suggested the presence of oxygen molecules, each made of two oxygen atoms, which are produced when charged particles erode Ganymede's icy surface. However, some of these ultraviolet emissions didn't match what you would expect from an atmosphere of pure molecular oxygen. Previous research suggested these discrepancies were linked to signals from atomic oxygen – single atoms of oxygen.

As part of a large observing program to support NASA's Juno mission, researchers sought to measure the amount of atomic oxygen in Ganymede's atmosphere using Hubble. Unexpectedly, they discovered there is hardly any atomic oxygen there, suggesting there must be another explanation for the earlier ultraviolet signals. The scientists focused on how the surface temperature of Ganymede varies strongly throughout the day, with highs of about -123 degrees Celsius at noon at the equator and lows of about -193 degrees Celsius at night.

At the hottest spots on Ganymede, ice may become sufficiently warm enough to convert directly into vapour. Researchers noted that differences seen between a number of ultraviolet images from Ganymede closely match where you would expect water in the moon's atmosphere based on its climate.

A composite image of Jupiter's largest moon, Ganymede

© Getty



Until recently, archaeologists thought the cave dated to the 18th century. Their estimate was nearly 1,000 years off the mark

HISTORY

Archaeologists find exiled Anglo-Saxon hermit king's lair

WORDS BEN TURNER

A British cave dwelling has been identified as the refuge of an exiled Anglo-Saxon king. Anchor Church, located by the River Trent in a secluded part of the countryside in central England, was long considered to be an 18th-century 'folly', an extravagant building made solely for ornamentation or as a joke.

But a recent study has revealed that the cave house is the real deal. The 1,200-year-old structure was built during the tumultuous life of the Northumbrian king Eardwulf, who was hounded from his throne to live as a hermit, and later became a saint. Local legend said Eardwulf, or St Hardulph as he was later known, lived inside the cave dwelling after he was deposed and exiled for mysterious reasons in 806 CE. A fragment from a 16th-century book states that Eardwulf "has a cell in a cliff a little from the Trent," and the banished king was buried in 830 CE at a location just five miles from the cave.

Edmund Simons, an archaeologist at the Royal Agricultural University in England, is convinced that Eardwulf lived in the caves under the watchful eyes of his enemies. "The architectural similarities with Saxon buildings, and the documented association with Hardulph/Eardwulf, make a convincing case that these caves were constructed, or enlarged, to house the exiled king," said Simons.

Eardwulf lived and ruled during a time of persistent political instability in medieval England. During the seventh, eighth and ninth centuries, seven key kingdoms and over 200 kings intrigued, murdered and warred against each other in a fervent, constant scramble for supremacy. Eardwulf took the throne in 796 CE after the killing of his two immediate predecessors, and ruled Northumbria for ten years before he was chased from power – possibly, according to some scholars, by his own son – to spend his remaining years in exile in the rival kingdom of Mercia. With all of this civil strife, hiding in a cave with the remainder of his disciples was far from the most abnormal idea Eardwulf could have come up with. "It was not unusual for deposed or retired royalty to take up a religious life during this period, gaining sanctity and in some cases canonisation," Simons said. "Living in a cave as a hermit would have been one way this could have been achieved."

Did you know?
Anglo-Saxons were farmer-warriors

The researchers reconstructed the original plan of the caves, which includes three rooms and an easterly facing chapel, using detailed measurements, a drone survey and a careful study of the architectural features, which closely resemble other Saxon architecture. Despite having been overlooked by historians until recently, cave dwellings may be "the only intact domestic buildings to have survived from the Saxon period," Simons said. The team has identified over 20 other cave houses in west-central England that could date back as far as the fifth century.

The Anchor Church caves were later modified in the 18th century, when it was written that the English aristocrat Sir Robert Burdett "had it fitted up so that he and his friends could dine within its cool and romantic cells". Burdett added brickwork and window frames to the caves, as well as widening the openings so that well-dressed women could enter.

STRANGE NEWS

Alien abduction stories may come from lucid dreaming

WORDS MINDY WEISBERGER

Lucid dreaming, in which people are partially aware and can control their dreams during sleep, could explain so-called alien abduction stories. Claims of such abductions date to the 19th century, and the circumstances of the kidnappings often sound dreamlike and trigger feelings of terror and paralysis.

Certain dream states are also known to produce such feelings, leading Russian researchers to wonder if dream experiments could provide clues about alleged extraterrestrial experiences. The scientists prompted lucid dreamers to dream about encounters with aliens or unidentified flying objects (UFOs), discovering that a number of sleepers reported dreams that resembled actual descriptions of alleged alien abductions.

During lucid dreams, sleepers are aware they are dreaming and can then use that awareness to manipulate what happens in the dream. About 55 per cent of people experience lucid dreaming once or more in their lifetimes, and 23 per cent have lucid dreams at least once a month.

Recently, researchers with the Phase Research Center (PRC) conducted experiments with 152 adults who self-identified as lucid dreamers, instructing them to "find or summon aliens or UFOs" during a lucid dream. The researchers found that 114 of the participants reported dreaming about having some type of successful interaction with an extraterrestrial. Of those, about 61 per cent described meeting 'aliens' that resembled extraterrestrials from science-fiction novels and films, while 19 per cent met aliens that looked like ordinary people.

Scientists guided lucid dreamers to emulate encounters with aliens and UFOs during REM sleep

One female participant spoke of seeing little men with blue skin, oversized heads and huge, bulging eyes. When the aliens invited her onto their spaceship, "I was blinded by a very bright light, like from a searchlight," she said. "My vision was gone, and I felt dizzy and light." Another participant said that he dreamt he was lying in his bed when he felt as though he were being "dragged somewhere," ending up in a room with a white silhouette that reached into his chest and started "doing something inside with tools".

Conversations with dream aliens took place in 26 per cent of the encounters, and 12 per cent of the participants spoke with aliens in their dreams and interacted with them physically. UFOs showed up in 28 per cent of the meetings, and 10 per cent of the dreamers who saw UFOs described being brought inside an extraterrestrial spacecraft.

Of those who described their encounters as realistic, 24 per cent also experienced sleep paralysis and intense fear. Such emotions often accompany reports of supposed alien abductions, and though individuals who describe being kidnapped by aliens might truly believe that they experienced was real, these people were likely experiencing a meeting while in a lucid dream.

HEALTH

MAN IN CHINA DIES OF RARE 'MONKEY B' VIRUS

WORDS RACHAEL RETTNER

A veterinarian in China has died after he contracted an extremely rare viral infection known to infect monkeys. The 53-year-old veterinarian is the first known human case of this virus, called monkey B virus, to be reported in China.

The man worked as a veterinary surgeon at a Beijing-based institute that specialises in experimental research in non-human primates. In early March he dissected two dead monkeys; a month later he developed a fever, nausea, vomiting and neurological symptoms. Despite treatment at several hospitals, the man died on 27 May.

Doctors diagnosed the man with monkey B virus, also known as B virus. The virus most commonly infects macaque monkeys, and it's rarely seen in humans – there have been just 50 human cases reported since it was discovered in 1932. But when the virus does 'jump' from monkey to person, it is often deadly. Of the 50 people infected, 21 have died. Most of the human cases have occurred in people who work with monkeys, such as veterinarians or researchers.

Once the virus jumps to humans, it doesn't spread easily between people. There has been just one reported case of a B virus infection in a human spreading to another person.

Macaque monkeys are common carriers of the monkey B virus

© Alamy / Getty

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Pets RADAR

PETCUBE PLAY 2
$199 (APPROX. £143.50) WWW.PETCUBE.COM

The Petcube Play 2 is very compact, and certainly looks the neatest of any of the specifically pet-led cameras we've reviewed. But it's not just the refined design that makes it a very cool camera. A wide-angle lens lets you see more of your room, and there's a quad-microphone array that helps you hear your pet, along with an upgraded speaker so that your pet can hear you more clearly.

Then there's the smarts: the Petcube Play 2 doesn't just link with Amazon's Alexa so you can trigger some of its features with your voice, it actually has Alexa built in, so you can ask it what the weather is like – or any other question that comes to mind – or use it to play music.

The camera is a high-resolution full-HD sensor with night vision and smart motion-sensing, so it can distinguish between whether it's seeing people or animals. Position one on your kitchen counter, for example, and you could set it up to alert you when your cat decides to investigate those forbidden areas.

There's no built-in treat-dispensing, but depending on your pet's proclivities that may be a positive. Instead there's a rather smooth – and less fattening – laser pointer to keep them entertained.

WICKED BALL
£36.03 / $49.99 WWW.CHEERBLE.COM

The Wicked Ball is packed with features that won't just keep your pet entertained, but will improve their fitness, too. This high-tech smart toy has been designed especially for pets to play with when they're left home alone for short periods of time, but its rugged nature means it's one of the best outdoor toys, too. It's best described as a tennis ball-sized toy that will roll around the floor, relying on sensors to avoid hard surfaces and giving its movements an unpredictability your pet will love. It will work equally well on carpet, grass or hard flooring.

JIOBIT LOCATION MONITOR
$149.99 (APPROX. £107.50) WWW.JIOBIT.COM

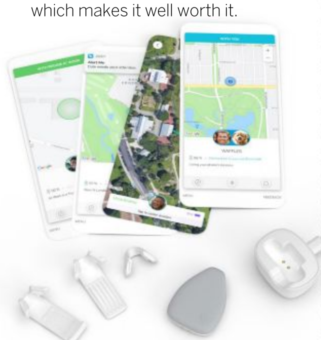
Bound to be the go-to pet tracker for 2021, this offering from Jiobit offers unmatched security and encryption, making it a great choice not just for your pet, but also for any small humans or seniors who might use it.

Tiny and long-lasting, with an impressive battery life of up to 20 days, the lightweight Jiobit weighs in at a tiny 22.7 grams, so your pet won't even know they're wearing it.

It has real-time GPS tracking and smart alerts, a next-gen, low-power 5G-compatible network and progressive beaconing technology that combines WiFi, cellular, GPS and Bluetooth to track your furry friend wherever they are.

Waterproof and durable, this nifty device features government-level encryption for maximum privacy and security, and it comes with several different attachments, allowing it to be worn in multiple different ways, so you can find one that suits your pet perfectly and won't irritate them.

You'll also need to purchase a subscription, which will set you back anywhere between $8.99 and $14.99 (approx. £6.49 and £10.80). But when it comes to tracking, the award-winning Jiobit is the best product on the market right now, which makes it well worth it.



IFETCH TOO

$199.99 (APPROX. £144) **WWW.GOIFETCH.COM**

The iFetch Too was created to match the fun of the original iFetch, but with larger dogs in mind. The result is a larger, more powerful launcher that can be adjusted to fire balls – including standard tennis balls – around 5 to 12 metres. Rechargeable batteries make things easier, and the device can be used inside or taken to the park or beach for outdoor fun.

But there are some issues raised with the iFetch Too. One of the most common problems listed is the quality of the balls provided and the impact they have on the device's mechanics. Additionally, the lack of a safety sensor means that balls can be launched while dogs stand directly in front of the device, risking injury.

SUREFLAP MICROCHIP CAT DOOR CONNECT WITH HUB

£183 / £243 **WWW.SUREPETCARE.COM**

The SureFlap Microchip Connect with Hub is a gadget lover's dream. The set comprises a generously sized cat flap and a hub that connects the door to the accompanying Sure Petcare app.

The kit offers all the usual benefits of a microchip cat flap in keeping unwanted guests at bay, plus a whole load of extras to connect you to your cat.

For example, the Sure Petcare app enables you to lock or unlock the pet door remotely, even when you're not at home. There's a 'curfew mode' that can be set up via the app so that the door is locked or unlocked at specified times of the day. The app also lets you check if your pet is at home – which is particularly great if you work late – and you receive a notification when your pet goes in or out via the pet door.

The cat flap requires four C cell batteries every six months or so, which are not always easy to find. Some users have also complained that it's not the easiest to set up, but it certainly offers many more features than the vast majority of cat flaps.

For more pet gadget reviews head to **petsradar.com**

SUREFEED MICROCHIP AUTOMATIC PET FEEDER

£86 / $149.99 **WWW.SUREPETCARE.COM**

If you have one cat who's not getting enough food because the other cats in your household are more brave, greedy or pushy at mealtimes, you can code this feeder to only allow one cat to access the food within.

It works in much the same way as company Sure Petcare's microchip pet flaps: your pet sticks their head in, a reader checks their chip and it opens if the correct pet is detected. Here it's not a simple case of unlocking, though, as the door covering the food bowl actively opens up while they remain in the vicinity, and automatically shuts a couple of seconds after they've left the bowl.

It's tough enough that the wrong pet won't be able to claw their way in, which is a great positive, but some users have reported that particularly canny cats have discovered a workaround. Pushing into the detecting halo once the door has opened and barging the correct pet out of the way leaves the food open for devouring because once the microchip reading is done the Automatic Pet Feeder is only concerned with proximity. That may not be the case for your pets, but it's certainly worth keeping an eye on dinner time.

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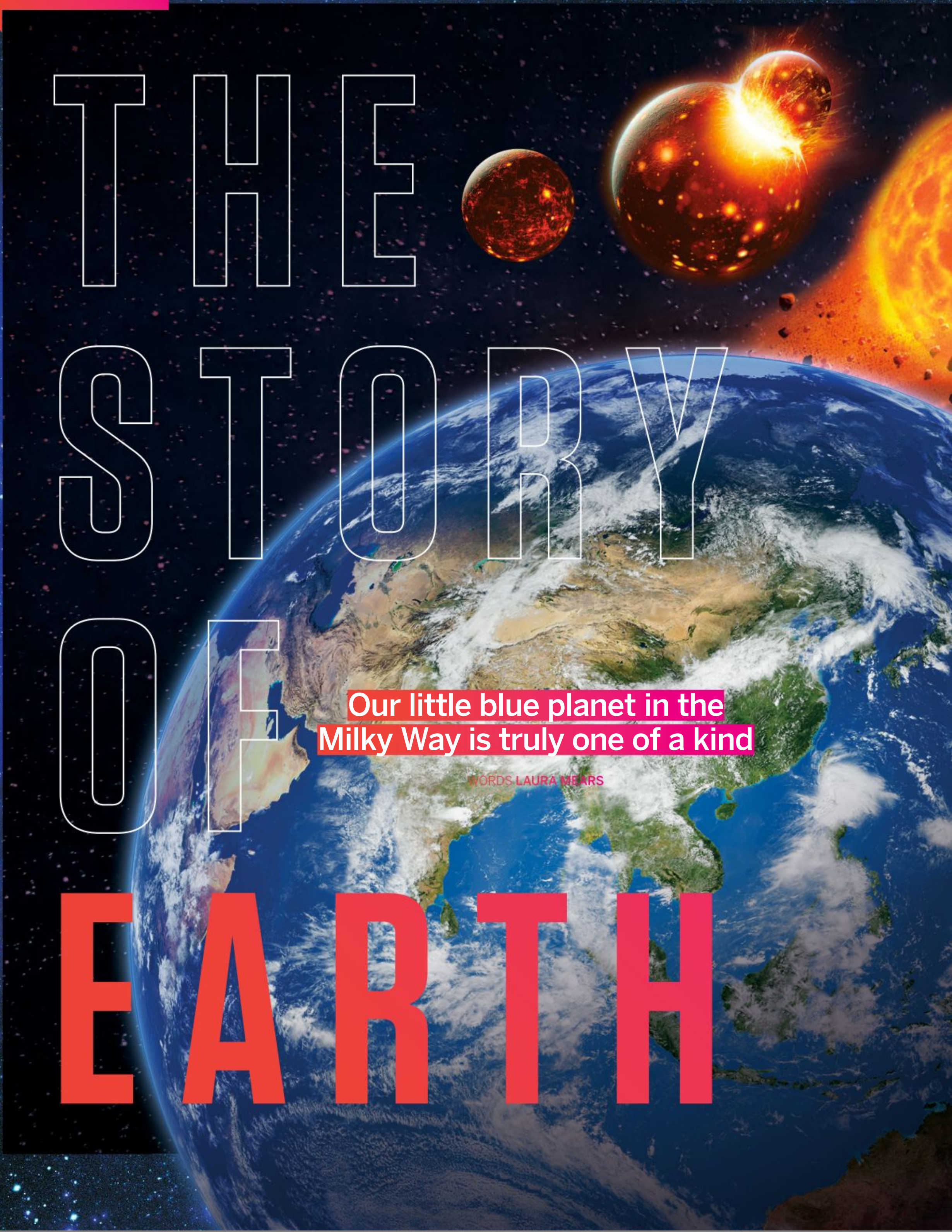


THE STORY OF EARTH

Our little blue planet in the Milky Way is truly one of a kind

WORDS LAURA MEARS

As far as scientists know, Earth is the only living planet in the galaxy. Born 4.6 billion years ago from a cloud of cosmic dust and gas, our 7,917.5-mile-diameter ball of rock is home to nearly 9 million different species – and has hosted many more millions since life began. The amount our planet has achieved over its relatively short life span is astonishing. But its journey from a lifeless rock to a paradise island in the cosmos hasn't been easy.

Earth wasn't one of the first planets in the universe – in fact, it's relatively young. Our Sun is a second-generation star, one of a group called Population I. It was born out of the remnants of much older stars after they ran out of fuel.

When the universe began 13.8 billion years ago, the only elements were hydrogen and helium. These lightweight gases formed the first bright, hot stars. Some of these stars had gas planets, but they didn't have rock or metal – as they didn't exist yet – and without those, life was impossible. The elements life needed were forged inside those early stars.

The heat and pressure within squashed the lightweight gases together to form the first 26 elements in the periodic table, up to and including iron. These are the elements that now make up the bulk of planet Earth, and its many inhabitants.

When those first stars ran out of fuel, they stopped fusing elements and started to collapse. Some became so unstable that they exploded. The blasts were so violent that they created even heavier elements, like gold and radioactive uranium, before showering the contents of the dying stars into space.

After the dust of the explosions settled, all that was left were clouds called nebulae. It was from one of these clouds that the Solar System emerged. Earth, and everything on it, is literally made of stardust.

Most of the rock that makes up the outer surface of our planet was forged in the first stars of the universe. These elements include oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium. Underground in the flowing rock of the mantle are more stellar elements – silicon, magnesium and iron – and right at the centre, in the liquid core, is a mixture of molten iron and a supernova element, nickel.

In its earliest days, Earth was just a hot rock in a lifeless star system. But the star-forged elements it contained gave it the power to become so much more. Ancient hydrogen combined with oxygen to make rain, coating the planet in vast oceans. Those oceans dissolved minerals from the first stars, becoming a salty chemical soup. Violent weather, volcanic activity and radiation from the Sun provided the heat and sparks to jolt that soup into life, and that changed our planet forever.

Every living organism on Earth is made of recycled stars, and most of them contain supernova dust, too. Inside your own body, iron allows your blood cells to carry oxygen, zinc enables your immune system to fight infection and selenium makes antioxidants that shield your cells from damage. The journey from cloud of dust to living planet has been a long one, but here we'll cover just how our lively planet evolved.

© Getty

THE BIRTH OF OUR PLANET

How a cosmic cloud gave rise to life

The Solar System was born from a cloud of dust called a nebula. A shock wave, triggered by the death of a nearby star, caused that nebula to collapse. It tumbled in on itself, forming a hot, white ball of matter that became so dense that atoms at its core started to fuse. These nuclear reactions gave birth to the Sun. Around that young star, the rest of the cosmic dust from the nebula continued to swirl. It formed small clumps that started to grow by a process called accretion. These clumps became the planets and moons.

The formation of the planets took millions of years, and it wasn't peaceful. As Earth was beginning to take shape, large chunks of rock and ice were still hurtling through the Solar System. They would crash into Earth at random, melting the ground and sending violent shock waves into the mantle. The biggest of these collisions was with a planet-sized rock called Theia, which formed our Moon. Though devastating, that encounter played a vital role in the evolution of our planet. It stabilised Earth's rotation, helping to steady the climate, and it created the tides.

By the time Earth started to cool, most of its water had boiled away into space, and in the early years it didn't even have an atmosphere. Luckily, another planet was on hand to help. Jupiter sits just beyond the asteroid belt. Its massive gravitational influence slows passing rock fragments, pulling them into orbit around the Sun. It acts as our protector, but also as a slingshot, sending some of those asteroids and comets right into our path.

The projectiles Jupiter hurled at our planet in the early years of the Solar System were full of hydrogen and oxygen, the raw ingredients of water. These elements melted into the mantle and came out as rain when ancient volcanoes erupted, turning the bare rocks of early Earth into mineral-rich oceans.

Did you know?
Earth's crust is about 46 per cent oxygen

IN THE BEGINNING
In the first 100 million years of the Solar System, rocks collided and collected to form a hot ball of rock and metal.

THE FIRST OCEANS
As Earth started to cool, water condensed in the atmosphere, raining down on the ground and forming the oceans.

SNOWBALL EARTH
As the continents shifted and life began to evolve, the atmosphere altered. Earth swung between periods of extreme heat and frigid cold.

THE RISE OF THE SUPERCONTINENTS
The tectonic plates continued to move relentlessly, shuffling Earth's continents into different configurations.

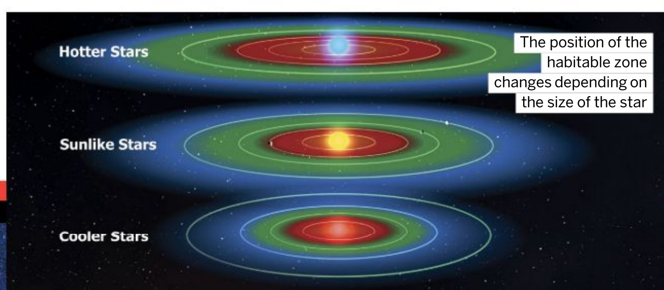
MODERN EARTH
Even today, the continents and the atmosphere are evolving around us.

EARTH'S EVOLUTION

The face of Earth has changed dramatically over its 4.5-billion-year history

THE GOLDILOCKS ZONE

The chemical reactions that make life possible can only happen in liquid. Gas molecules are too far apart to interact, and solids can't move around enough to mix together. That's why water is essential. There's no other liquid in the universe that behaves quite like it. Made from one oxygen atom and two hydrogens, water molecules have a special chemistry. They can dissolve almost anything, allowing the chemicals of life to mix and react. The Goldilocks zone is the space around a star where water can exist in its liquid form: not too hot and not too cold, but just right for life to evolve.



The position of the habitable zone changes depending on the size of the star

DID YOU KNOW? Mercury and Venus don't have any moons. Mars has two, and Jupiter and Saturn have more than 70 each

WHERE THE MOON CAME FROM

Our closest celestial companion formed after a ball of rock named Theia hit Earth

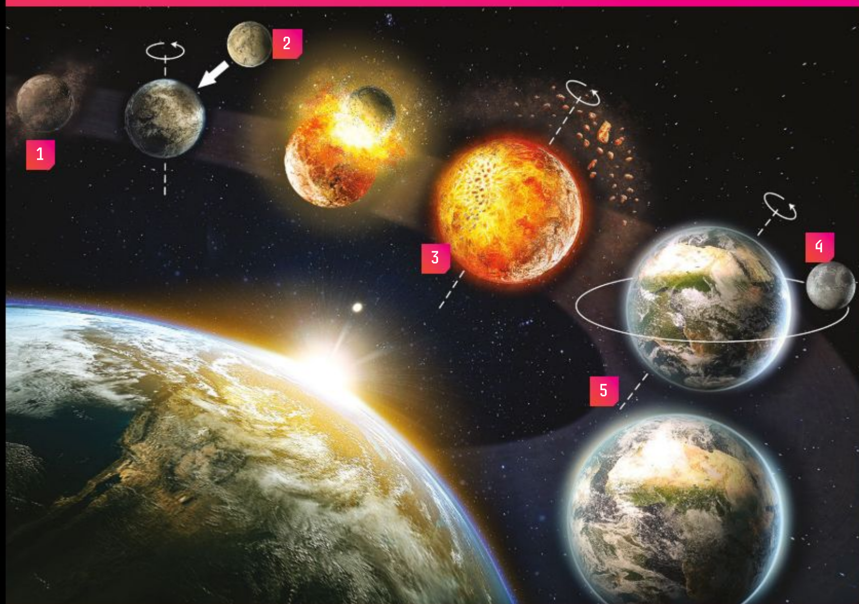
1 EARLY EARTH
The young Earth was a hot ball of rock and metal.

2 THEIA
4.5 billion years ago, a rock around half the size of Earth crashed directly into our young planet.

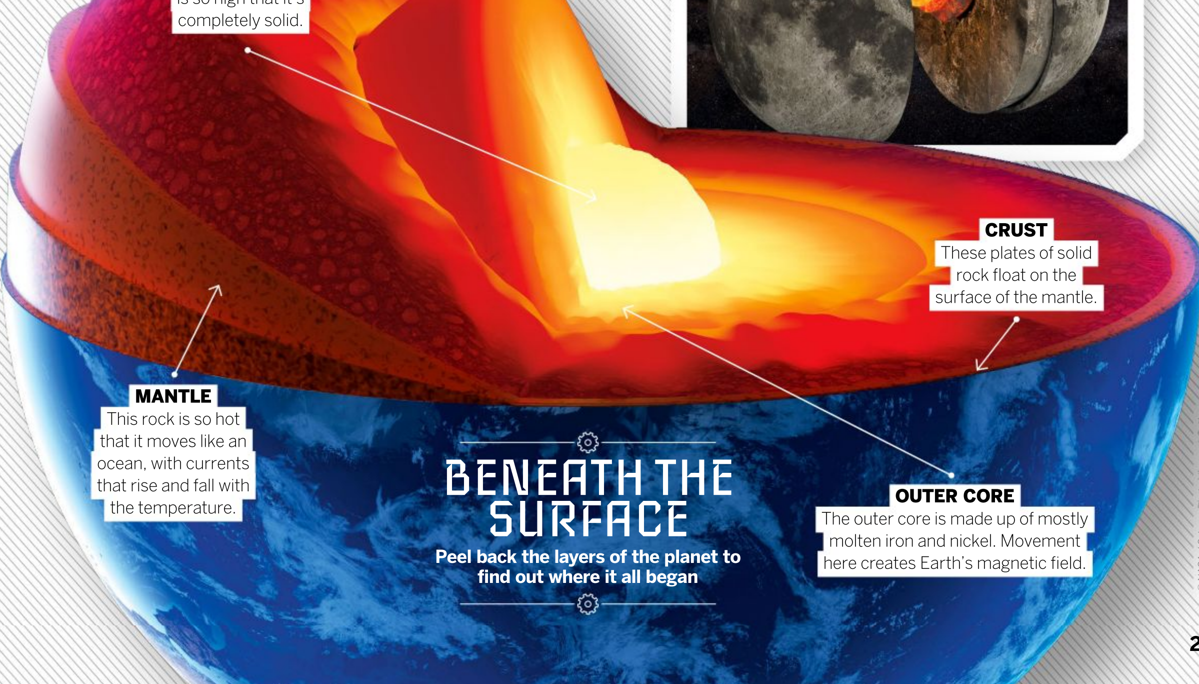
3 THE AFTERMATH
Theia and Earth combined with such force that the surface of the planet turned into rivers of magma.

4 THE MOON
The impact shot debris into orbit around Earth. The lightest elements boiled away, and the rest became the Moon.

5 TILTED AXIS
The collision knocked Earth sideways, toppling its axis into a tilt that wobbles between 22.1 and 24.5 degrees.




Earth and the Moon share chemical elements – both have a nickel-iron core



BENEATH THE SURFACE

Peel back the layers of the planet to find out where it all began

© NASA / Science Photo Library / Getty

This NASA image shows hurricanes forming in the atmosphere over the Atlantic Ocean

EARTH'S EVOLVING CLIMATE

From hot to cold and back again

Just after the birth of the Solar System, in the Hadean Eon, the entire Earth was liquid, a hellscape of fire and lava. The planet was still being pummelled from all directions by meteor strikes. As Earth started to cool, a crust of solid rock began to appear on its surface, but at first it was very fragile. Repeated impacts and volcanic eruptions broke that crust into chunks called tectonic plates, which floated on the magma below.

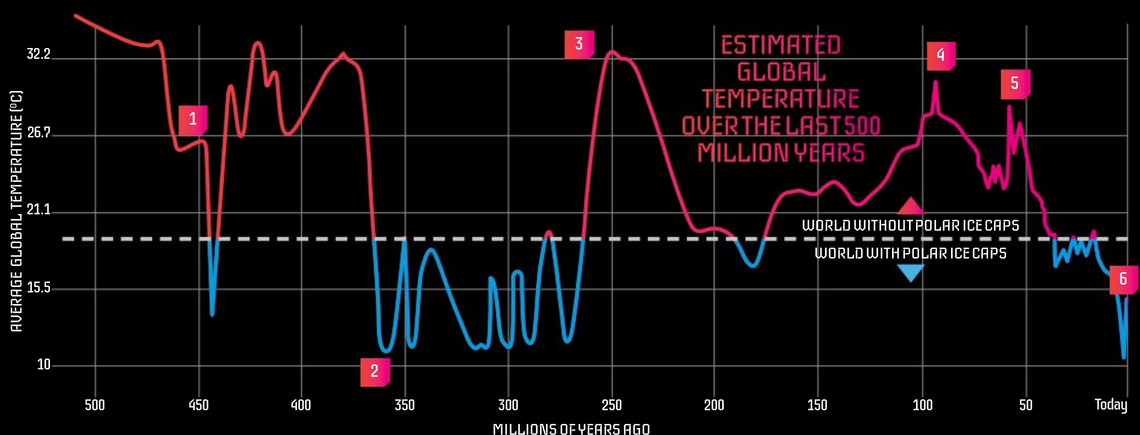
During the Archaean Eon, 4 to 2.6 billion years ago, the plates started moving, but when they collided, the heat of the mantle would break them apart. They had to stop, cool down and recover before they could start moving again. By the time this eon came to an end, tectonic plates had become more stable, and they had started to move constantly. Across history the plates have continually collided and separated, forming and reforming different patterns of continents and oceans.

These movements have had dramatic effects on Earth's climate. When continents break apart, the exposed rock absorbs carbon dioxide from the air, and global temperatures plummet. As volcanoes erupt, the greenhouse gases break free again and blow back into the atmosphere, trapping heat from the Sun. Events like these have triggered enormous freeze-thaw cycles in Earth's past.

"As Earth started to cool, a crust of solid rock began to appear"

Earth's position in space has influenced global climate too. After its collision with Theia, Earth's axis fell into a tilt, creating the seasons. That tilt has always been unstable, and so has the shape of Earth's orbit around the Sun. Our distance from the Sun changes on a 100,000-year cycle, tipping us in and out of ice ages. For the first part of Earth's existence, its climate was entirely dominated by these quirks of space and geology, but when life evolved everything changed.

During the Proterozoic Eon, evolution invented photosynthesis. The atmosphere filled with oxygen and gained a protective shield called the ozone, making it possible for living organisms to start terraforming the land. Our impact on the climate has been monumental, and today humanity is one of the most powerful forces of climate change.



1
450 million years ago
A thick, carbon dioxide atmosphere blanketed the entire Earth. The ocean was around 35 degrees Celsius.

2
360 million years ago
Plants covered the land, stripping carbon dioxide from the air. Temperatures dropped and the poles froze.

3
260 million years ago
Temperatures shot up again as volcanoes became more active, melting the ice and scorching the equator.

4
90 million years ago
Carbon dioxide levels skyrocketed, causing a period of warming called the Cretaceous Hot Greenhouse.

5
55 million years ago
The Paleocene-Eocene Thermal Maximum occurred – the world's most dramatic climate change event.

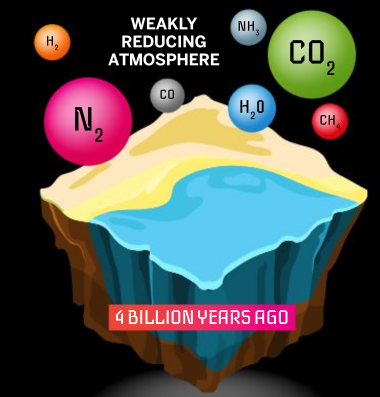
6
Today
Global average temperatures are rising sharply as greenhouse gases trap heat in the atmosphere.

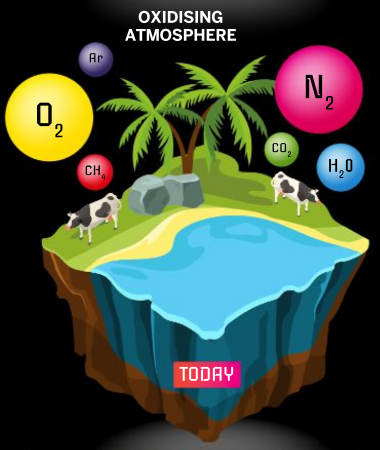
FORMATION OF THE ATMOSPHERE

Earth lost all its air almost as soon as it formed. Most of the gas was hydrogen and helium, and Earth's gravity simply wasn't strong enough to hold it down. This meant that in the earliest days, there was no air at all.

Earth's first atmosphere emerged from the belly of the planet. Gases bubbled up to the surface during violent volcanic eruptions, covering the ground in a hot blanket of carbon dioxide, nitrogen and water. Then came the rain. The water leaked out of the atmosphere in torrents that formed the first oceans, leaving nitrogen as the dominant atmospheric gas.

When life eventually evolved, the atmosphere changed again. Photosynthesising organisms pulled carbon dioxide from the air and split it apart, turning the carbon into food for their bodies and spitting the oxygen back out as waste. As that oxygen started to build up, ultraviolet light from the Sun shattered it into pieces. Those pieces recombined to make the ozone layer.





THE MAKING OF THE CONTINENTS

Plate tectonics shift the ground beneath our feet, changing the face of the Earth

AR zone

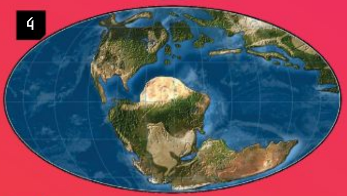
SCAN HERE

1

2

3

4



5

6

1 RODINIA
1.3 TO 1 BILLION YEARS AGO

Fragments of Earth's crust pushed together to form the first supercontinent, lifeless rocks surrounded by a stormy ocean.

2 LAURENTIA
425 MILLION YEARS AGO

Heat tore Rodinia apart, releasing Laurentia, a vast land mass that would go on to become North America, Europe and Asia.

3 PANGAEA
237 MILLION YEARS AGO

The fragments of Rodinia rejoined to form Pangaea, upon which dinosaurs and mammals first evolved.

4 GONDWANA
152 MILLION YEARS AGO

Pangaea split apart into two great landmasses, with Laurasia to the north and Gondwana to the south.

5 MODERN EARTH
TODAY

Laurasia broke apart to form North America, Europe and Asia. Gondwana split into Africa, South America, India, Antarctica and Australasia.

6 FUTURE SUPERCONTINENTS
200 TO 300 MILLION YEARS FROM TODAY

The next supercontinent is due to form 200 or 300 million years from today, but exactly what it will look like is still something of an unknown. Scientists predict four possible scenarios: Novopangaea, Pangaea Proxima – or Ultima – Aurica and Amasia.

Novopangaea will form if the Atlantic Ocean continues to widen and the Pacific continues to close; this will cause the Americas to smash into Antarctica and Eurasia. Pangaea Proxima will form if the Atlantic starts to close, bringing the continents back together. Aurica will form if both the Atlantic and the Pacific Oceans close, sandwiching the Americas between Australasia and Antarctica and Eurasia. And Amasia (not shown) will form if the continents drift northwards and collide in the Arctic circle.

© Getty / Earth's plates illustration: Nicholas Forder

SPECIAL

THE ORIGIN OF LIFE

One common ancestor gave rise to all things

Life on Earth is like nothing else in the universe – at least that we know of. Our planet is home to an estimated 8.7 billion different species. The smallest is the 400-nanometre microbe *Nanoarchaeum equitans*; the largest the six-mile honey fungus. Both of them, and everything in between, can trace their evolutionary ancestry back to a single species, known as the last universal common ancestor, or LUCA.

LUCA was a single cell with a little loop of genetic code carrying 100 essential genes, which it passed on to almost every organism alive today. A microbe, it lived 3.5 billion years ago in a hot volcanic vent deep beneath the surface of the ocean. There was no oxygen to breathe at the time, so LUCA survived on hydrogen, carbon dioxide and nitrogen. It made its energy using the natural gradient of ions that exists between hot thermal vent water and cold seawater.

"We can trace evolutionary ancestry back to a single species"

LUCA gave rise to all three branches of the tree of life: the archaea, the bacteria and the eukarya. Each branch has left its mark on Earth, changing everything from the composition of the atmosphere to the shape of the land, the climate and the weather.

The archaea are the oldest and perhaps the strangest of Earth's organisms. They live in places no other life can survive, like boiling vents, bubbling acid and frozen ice.

The bacteria are the smallest and most prolific. These single cells have colonised almost every corner of the planet. Scientists estimate that there are 5 million trillion trillion of them alive today – that's 5,000,000,000,000,000,000,000,000,000,000!

For millions of years, most of Earth's life was underwater

Today the vast majority of Earth's animals live on land

PRIMORDIAL SOUP THEORY

Could life really have started in a warm little pond?

VOLCANIC ORIGINS

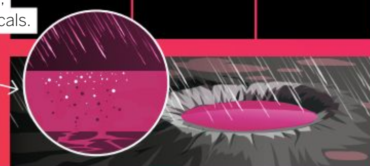
Earth's early atmosphere was a hot mixture of carbon, nitrogen and hydrogen-containing chemicals like carbon dioxide, methane and ammonia. There was no oxygen, and violent volcanic eruptions threw dust and ash into the air, creating rocky islands in the ocean.

A SPARK

The heat of the Sun, the impact of asteroids and the arcing electricity of lightning acted as catalysts. They triggered the production of hydrogen cyanide, which dissolved into pools of water on the ground.

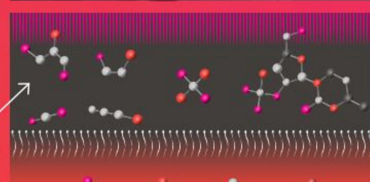
HEAT AND LIGHT

Under the hot ultraviolet light of the Sun, hydrogen cyanide reacted with other chemicals in the water, forming cyanide salts. As the water evaporated, these salts became a concentrated crust of chemicals.



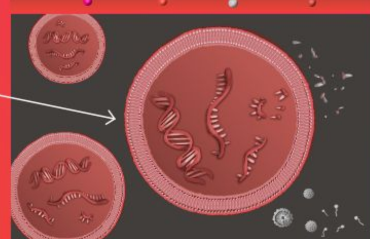
CREATING CHEMISTRY

In the presence of these cyanide chemicals and phosphates, the other hydrogen, carbon and nitrogen-containing compounds in the water reacted together. They formed nucleotides, the building blocks of genetic material.



PROTOCELLS

Fatty acids in the water closed around these early strands of genetic code, forming tiny cell-like bubbles. More fats joined the bubbles, allowing them to grow and divide. The new bubbles took pieces of genetic code with them.



The eukarya are the youngest and most diverse of Earth's creatures. They include almost all life you see around you, from plants and animals to fungi, yeast and amoebae. LUCA was the shared ancestor of everything, but it wasn't Earth's first life form. Fossil evidence of life on Earth dates back as far as 3.7 billion years, and scientists believe that the first living organisms emerged even earlier.

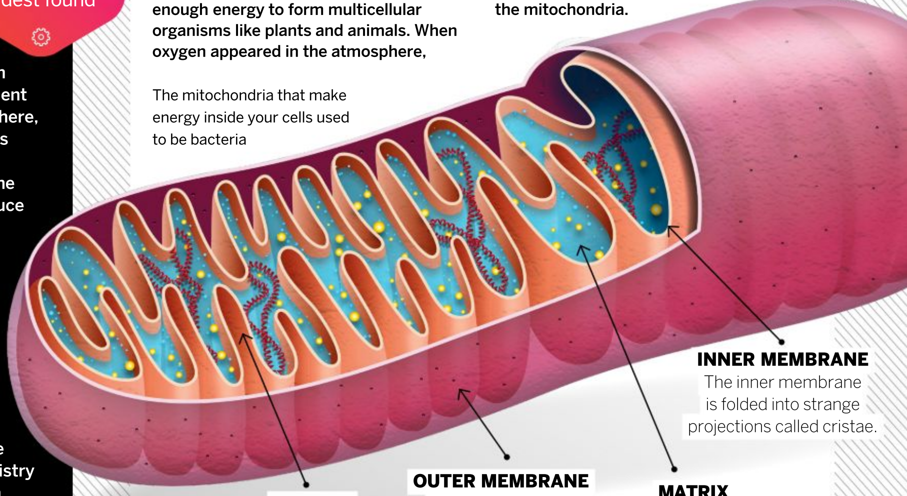
The very first living organism had to come from something not living, a process that scientists call abiogenesis. But how that happened is still a mystery. What we do know is that life began when Earth was in its Hadean Eon, a time when rust was raining down on the planet. Violent iron hailstorms tore through the atmosphere, reacting with water to form red dust. This reaction produced hydrogen as a waste product, and that hydrogen was key to the formation of life. It had the power to reduce other chemicals, adding electrons and stripping away oxygen. These reduction reactions created the three building blocks of life: nucleic acids, fatty acids and amino acids.

Alone these building blocks are not alive, but when they combine, something incredible happens. Strings of nucleic acids form RNA and DNA, the carrier molecules of genetic code. Strings of amino acids form proteins, the molecular machines that drive the chemistry of living organisms. And fatty acids form bubbles called membranes, which separate life from the rest of the world. Scientists disagree about which of these molecules came first, but it was the combination of the three that made life on Earth possible.

Did you know?
Stromatolite fossils are the oldest found

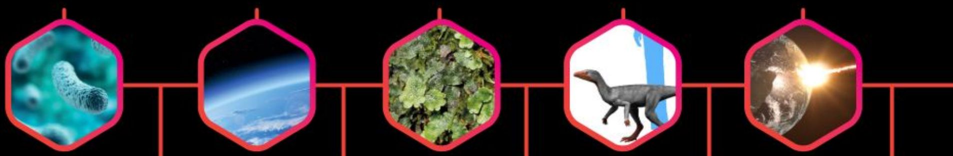
WHERE DID OUR CELLS COME FROM?

One of the biggest events in the history of evolution was the development of mitochondria, the energy factories of all complex cells. Scientists think that they only evolved once, an event that completely changed the course of evolution. For billions of years, life was just single cells. It was impossible to make enough energy to form multicellular organisms like plants and animals. When oxygen appeared in the atmosphere, some cells learned how to use the new gas. In a chance event, one of these oxygen-breathing cells got inside a larger cell and started dividing. The two types of cell started to work together to make more energy than ever before. Over time, their relationship became permanent, and the oxygen-breathing cells became the mitochondria.



The mitochondria that make energy inside your cells used to be bacteria

THE EVOLUTION OF LIFE ON EARTH



3.8 BILLION YEARS AGO
The very first microbes appeared: simple organisms with just a single cell.

3.5 BILLION YEARS AGO
LUCA emerged – the organism from which every creature alive on Earth today has evolved.

2.4 BILLION YEARS AGO
Runaway photosynthesis caused the Great Oxidation Event. A mass extinction began as ancient organisms struggled to cope with rising oxygen.

1.7 BILLION YEARS AGO
Organisms with more than one cell began to emerge. First sponges, then fungi and corals.

500 MILLION YEARS AGO
Under the cover of the newly formed ozone layer, the Cambrian explosion began, and thousands of animal species evolved.

367 MILLION YEARS AGO
The first four-legged animals, called tetrapods, started to evolve, making way for the colonisation of land.

225 MILLION YEARS AGO
The very first dinosaur appeared, marking the beginning of a multimillion-year planetary takeover.

178 MILLION YEARS AGO
The very first mammals started to emerge, but dinosaurs put the brakes on their evolution.

66 MILLION YEARS AGO
An enormous asteroid triggered the Cretaceous-Paleogene mass extinction event, wiping out non-avian dinosaurs.

50 MILLION YEARS AGO
Mammals filled the gaps left by the dead dinosaurs, becoming the most dominant group of animals on the planet.

© Getty / Primal soup illustration: The Art Agency: Nick Sellers / Dinosaur: Wiki/ Nobu Tamura

THE HISTORY OF EARTH

13.8 BILLION YEARS AGO
The Big Bang gave birth to the universe in a blast of intense heat.

4.6 BILLION YEARS AGO
The Sun burst into life, a nuclear reactor at the centre of a brand-new star system.

4.5 BILLION YEARS AGO
Young Earth started to cool. Metals sank to its core, and rocks formed a crust on its surface.

4.4 BILLION YEARS AGO
It rained for the first time, covering Earth's surface in deep, dark oceans.

3.8 BILLION YEARS AGO
The first signs of life emerged, and began changing Earth's chemistry forever.

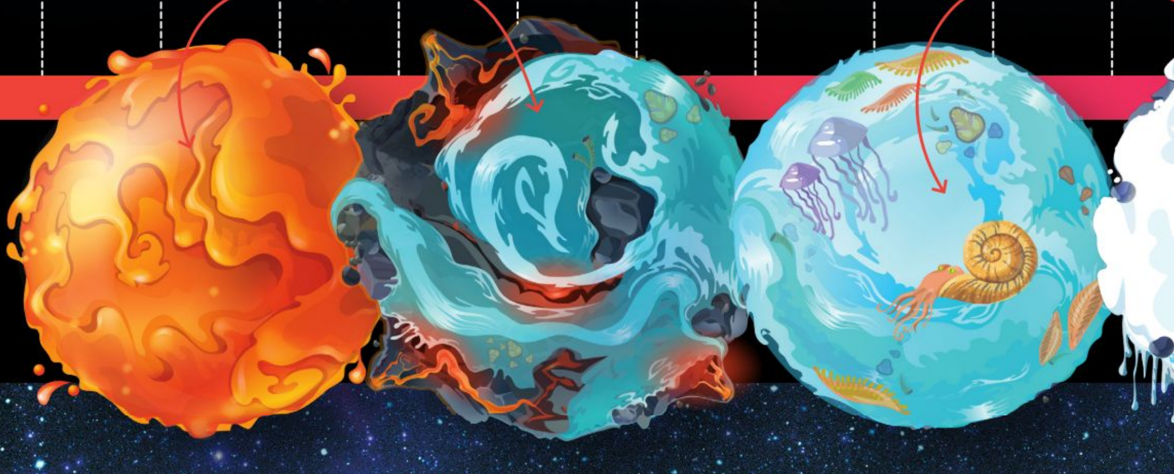
3.4 BILLION YEARS AGO
Microbes started photosynthesising. Most of the oxygen they made reacted with iron and sank to the bottom of the sea.

1.5 BILLION YEARS AGO
Free iron ran out, and the oxygen released by photosynthesis started to build up in the atmosphere.

750 MILLION YEARS AGO
A long and deep ice age descended, transforming Earth into a giant snowball.

530 MILLION YEARS AGO
Fish with backbones evolved – the ancient ancestors of all animals with backbones.

443 MILLION YEARS AGO
Freezing temperatures descended on Earth once again, causing one of the largest extinction events in history.



DID YOU KNOW? Earth is the biggest of the four rocky planets in the Solar System, larger than Mercury, Venus and Mars

21

THERE HAVE BEEN 21 DIFFERENT SPECIES OF HUMAN IN EARTH'S HISTORY

The first known land animal was a millipede called *Pneumodesmus newmani*

21%
Not much of Earth's air is breathable oxygen

96%
Most of Earth's water is salty

99%
Almost all of the species that have lived on Earth are now extinct

332.5 MILLION CUBIC MILES
Earth contains a staggering volume of water

EARTH WAS COMPLETELY FROZEN WHEN ANIMALS FIRST EVOLVED

3 TRILLION BARRELS
Extinct animals left behind a huge amount of oil

5
Scientists count just a few mass extinction events in Earth's history

The asteroid that killed the dinosaurs left a 93-mile-wide crater called Chicxulub

Earth's radius is 3,959 miles as the fifth-largest planet

400 MILLION YEARS AGO
Plants left the ocean and colonised the land, turning Earth's bare ground green for the first time.

360 MILLION YEARS AGO
Another mass extinction event swept Earth, wiping out 80 per cent of all animals, most of them in the sea.

350 MILLION YEARS AGO
Animals followed plants onto the land, making way for the evolution of thousands of new species.

252 MILLION YEARS AGO
Rising temperatures triggered the Great Dying, killing over 96 per cent of sea animals and 66 per cent of land animals.

201 MILLION YEARS AGO
Life faced another setback as rising greenhouse gases killed off 80 per cent of all animals. Their remains turned into oil.

150 MILLION YEARS AGO
Bees evolved from hunting wasps, and soon after flowering plants appeared.

66 MILLION YEARS AGO
An asteroid impact wiped out the dinosaurs, along with 76 per cent of all other species.

2.4 MILLION YEARS AGO
The first humans evolved in Africa, a species known as *Homo habilis*.

200,000 YEARS AGO
Modern humans appeared in the Horn of Africa: our species, *Homo sapiens*.

1760
The industrial revolution began, marking one of the most rapid periods of climate change in Earth's history.

© Getty

HOW TO SURVIVE ALMOST ANYWHERE

Could you escape the wilderness with the bare minimum of tools?

WORDS **ANDY EXTANCE**

It's the stuff of nightmares – suddenly you're on your own, somewhere wild, with nothing to help you survive. Could you make it out alive? Here we aim to give you some tips that might improve the chances of that. It's not an SAS-style survival bible, but a few things it would be useful to remember in a pinch.

In order to survive, we all need food, water, shelter, warmth and air. In most places on Earth, air is not a problem – so this won't cover the places that are. But you should start thinking of the other four points as quickly as possible if you ever find yourself in a survivalist situation.

Your first step if you are suddenly lost in the wilderness is usually to make a safe, comfortable shelter, start a fire and find a safe water source. Next, carefully assess your environment, looking for landmarks and working out which way is north, and make a plan. List everything that you have that you can use. This will help calm you down and boost your morale. If people know where you are, your best bet is to stay still until they find you. Similarly, if you can use smoke from your fire or a shiny surface to signal with, you could try to stay where you are and signal people to come to you.

Yet the plan will differ according to your environment and circumstances. People probably won't know where you are if you've washed ashore on a desert island. Extremes of heat and cold are especially challenging for finding enough to eat and drink. And in jungles, insects pose particular problems.

Whatever you do, don't panic and rush away unprepared. Take the time you need to make sure you're as well equipped as possible for your environment – that way you might get back safely.

FINDING LIFE-GIVING LIQUID

You need to drink several litres of water every day. Here's how to find it

Without water, you'll die in a few days. Your body is three-quarters water by weight. You lose water when sweating, peeing and pooping. This all has to be replaced. Even in comfortable climates your body needs about two litres a day to stay healthy. You need much more if you're travelling in hot places. Some recommend drinking a litre for every four miles covered, even if travelling at night, and twice that in the day. In cold places you also need more water because it's harder to move around and you need to generate more heat. You also need water to cook with, and to keep yourself clean.

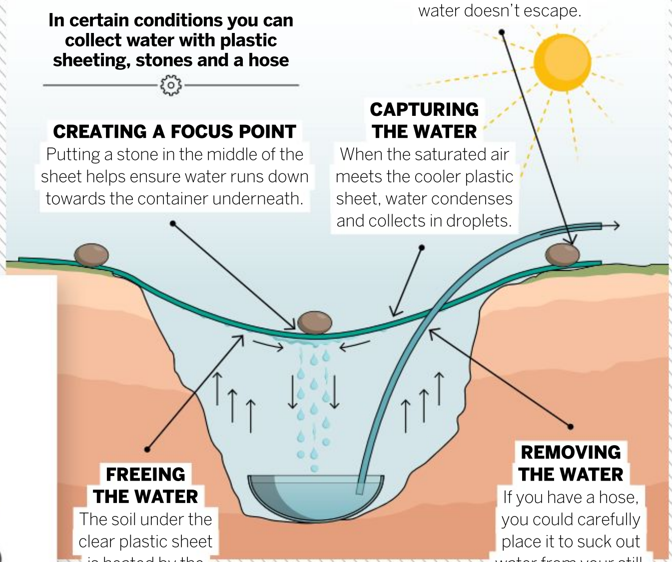
In fact, you need so much water, it's best to find reliable, clean sources like rivers and stay fairly close to them. That's especially difficult in deserts, where you need most water. You could try following a dried-up river bed in the hopes of finding a stream. Salty desert lakes can be found, in which case digging a shallow hole about 30 metres from the lake may yield potable water, as rain from the dunes travelling to the lake will gradually gather there. You can do something similar on beaches.

Finding water in rocky places can be hard, but you should look for springs and seepages. For example, in a clay landscape you might see an area with more plants where the rock is wetter. In jungles water is often plentiful, but contaminated. Water purification tablets are best here, but you can filter water through fabric. You can also find water pooled on big leaves or in tree trunks, but you should purify this too.

Given water is so important, it's good that there are many ways to find it. It's worth remembering a few ways, in case you're ever in desperate need of a drink.

MAKING A SOLAR STILL

In certain conditions you can collect water with plastic sheeting, stones and a hose



ATTITUDE AS A SURVIVAL TOOL

Panic is never helpful, and in the wilderness it can be lethal. Instead, survival experts stress the need for a positive mental attitude. You can use the adrenaline flooding your system from your fear to your advantage. Keep your imagination on a leash. Don't let it run wild, thinking about the different catastrophes you may face. Try to fight pessimism, and believe that you will survive. That can be hard, so to keep panic under control, focus on small, productive tasks. Don't let yourself get lazy or complacent.

Make a list of key survival jobs, like making a shelter, and get them done well

ESSENTIAL KIT

If you plan to go into the wilderness, you should tailor your survival kit to your environment. But there are common themes. You should have some means of starting a fire for cooking and warmth. Opinions differ over the best option, but waterproof matches are effective. A good knife is essential, and for extra versatility you could make this a multi-tool, like a Swiss army knife. A whistle is important for signalling if you see people, and can scare away animals. A small torch is vital for providing light. A compass will help ensure that you're not travelling in circles.

Survival kits contain tools and gadgets that aren't found in a simple camping

© Getty / Illustration Ed

HOW TO FIND WATER

There are many ways to find water in the wilderness. Here are four top tips

DESALINATE SEAWATER

ENVIRONMENT: ISLAND

On an island you're surrounded by undrinkable water. You can boil it and capture the steam in a cloth. When it's soaking wet, you can wring out pure water.

FOLLOW THE ANIMALS

ENVIRONMENT: ANY

Everything from bees to bears to birds need water. Frogs in particular need it. If you see anything living, carefully follow them. They should lead you to water.

LOOK FOR PLANTS

ENVIRONMENT: DESERT

In a desert, look for where plants are growing, as they need water. Try to get up high and look downwards, as water is often found in low, shaded areas.

CUT THE ICE

ENVIRONMENT: ARCTIC

Eating snow doesn't actually get you much water, and melting ice needs lots of fuel. One good way to get water is cutting through a frozen lake or river surface.

WARNING!

BEWARE OF BAD WATER

Never drink from water that has dead animals or animal remains in it. The water probably has lots of minerals in it and has become toxic. You have the same problem with seawater – it's too salty to be healthy to drink. Sadly, birds and animals can sometimes drink water that's unsafe for people, so you can't ignore other clues if they're drinking water that looks bad.

FINDING A PLACE TO REST

A good place to relax is essential, but don't think you can sleep on open ground

Shelter can give you both a physical and mental boost. In cold environments, the only way you can rest is in a warm shelter, out of the wind. In a hot place a shelter could protect you from getting too hot. But even when things are fairly comfortable, a shelter can give an added boost of better sleep and feeling cosier. It will protect you from unpleasant changes in the weather, or interruptions from animals and biting insects.

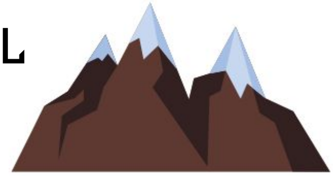
The kind of shelter you choose will depend on how much time you have available to set one up, and how long you intend to use it. For just one night there are various simple shelters you could make, or you could use a natural shelter. If you need to stay for longer, you should improve the shelter to make yourself more comfortable.

There are also unique considerations in different environments. If you are somewhere cold and snowy your shelter needs to be easy to build, because the cold saps your energy. It should also be windproof and warm, but let enough air out to avoid suffocating yourself.

Insects are a big problem in jungle environments, and can be hard to avoid if you haven't planned to be sleeping wild. At the very least you should try to shelter away from bodies of water, and with something between you and the ground. That could just be a piece of fabric, but if you can raise yourself higher off the ground, that would be even better.

FINDING NATURAL SHELTERS

Using landscape features can help you find shelter more easily



TREE BOUGH

ENVIRONMENT: JUNGLE OR FOREST

You can easily shelter under the bough of a tree, especially if it has fallen over naturally, or you can tie down a bough. Bough shelters are good camouflage.

CAVE

ENVIRONMENT: ANYWHERE ROCKY

A cave is an ideal shelter as it offers a roof, fairly constant temperature and is secure. However, you need to look out for other occupants, like snakes and bears.

NATURAL HOLLOW

ENVIRONMENT: TEMPERATE

A shallow depression in the ground will offer you some shelter from wind. You can also cover it with branches, grass, turf and bark to deflect rain and sunshine.

TREE PIT

ENVIRONMENT: ARCTIC

If you see a tree with thick lower branches surrounded in deep snow, you can dig a pit near the trunk to shelter in. Keep it small to retain heat.

DID YOU KNOW? Mauro Prosperi survived in the Sahara for nine days in 1994 by killing and eating bats and licking dew off rocks

BUILDING AN IGLOO

1 CUT BUILDING BLOCKS Cut blocks from hard, dry snow about a metre wide, 40 centimetres high and eight centimetres deep.

2 SURROUND THE HOLE Cut a circular groove around the hole you've just cut the blocks out of, deeper at one end than the other.

3 PILE UP THE BRICKS You can now stack up the snow bricks in a continuous spiral, overlapping so that they lean inwards.

4 MAKE AN ENTRANCE Cut a tunnel under the wall on one side. As well as being a way in, this traps cold air.

5 FILL THE HOLE Put the last block on top of the igloo. It will be larger than the hole, so needs shaping.

6 FINISHED IGLOO The finished igloo is warm – so warm it needs ventilation holes to avoid it melting.

AR zone

SCAN HERE

TOP TIP!

AVOIDING TOILET TROUBLE

Hygiene is very important in the wilderness to avoid disease and insect infestation. Flies are annoying and can carry diseases. You should therefore designate a latrine space well away from your shelter, where the prevailing wind will blow the smell away. If possible, dig a hole to use as a latrine. You should poke around for biting insects with a stick before you sit over it. In rocky areas you may just need to cover your waste with stones.

Fire can be used to warm yourself, as well as cook meals and distil water

BRIGHTEN YOUR CHANCES WITH FIRE

A fire can keep you warm and dry, but also provides many more benefits

When it comes to survival, few things boost your mental attitude like fire. It's near the top of the list of wilderness tools because it's so versatile. You should build one as soon as you have shelter. It can help dry your clothes, cook meals, sterilise water, repel insects, make tools, cast light and do many other things. But it's not always easy to make a fire.

The best conditions for making a fire will be when it's fine and dry, with a light breeze. This kind of weather is ideal for practising how to do it. But often in the wilderness it will be rainy. Then you'll need to find shelter, for example a rock shelf. A large tree or tarpaulin might also work, but need to be far enough away as to not risk setting them on fire. You can also find a fat log, split it open and light a fire from underneath. You should be able to find dry wood for fuel in sheltered spots.

If you're building a fire on wet ground, mud or snow, you could make a log platform to start your fire on. If you're somewhere so windy it makes it hard to get a fire started, you can dig a pit to start it in.

Often you will be able to find wood to build a fire with, but that may not always be possible in arctic conditions. In these chilly circumstances, you may be able to burn peat, rotten vegetation that looks a bit like soil, seaweed or animal dung.

Thankfully, there are many ways that you can design a campfire. We only touch on a few here, but there are lots of different options depending on your circumstances. If you're serious about learning wilderness survival, it's important to carefully practise making them.

© Getty / Illustration: Nicholas Forder

MAKE FIRE WITHOUT MATCHES

There are many ways to make fire without matches, but they take practice

WARNING!

BE CAREFUL WITH FIRE

Fire is essential if you're trying to survive in the wilderness, but it's also a great hazard. Burning yourself would make things much harder, and in the worst case you could die. You should always avoid windy areas where the fire can flare up out of control. Make sure there's nothing that can burn right near your fire. And when you move on, put out your fire.

FLINT AND STEEL

Scraping metal along flint – the hard, grey, easily breakable rock – makes sparks. If you catch the spark in a tinder ball, the tinder can catch on fire. The metal could be a knife, or part of a premade flint and steel.

MAGNIFYING LENS

It can take a long time, but on sunny days you can set fire to tinder with a magnifying lens. To do this you have to focus the light to a fine point. You could use eyeglasses, a magnifying glass or a binocular lens.

BOW AND DRILL

A bow is a curved piece of wood with a string attached. The drill is a hard wood spindle placed in a hole in a hard wood baseboard, with tinder in. Looping the string around the spindle and moving it back and forth ignites tinder through friction.

BUILDING A SIMPLE FIRE

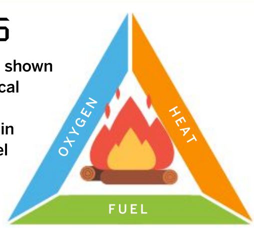
KIT LIST

- **Tinder: Easy-to-burn fine material such as shredded dry bark**
- **Kindling: matchstick-thick twigs**
- **Fuel: thumb-thick twigs**
- **Matches**

Choose a fire site, and clear the ground to expose bare earth. Build a hearth by placing your thumb-thickness fuel twigs side by side. Kneel by the fire to protect it from the wind. Now pile the kindling on top of the hearth, propped up in a tent shape. Then put the tinder in the gap in the kindling tent. Strike a match, shielding the flame from the wind, and light the tinder. If it's slow to burn, blow on it gently to add more oxygen. It should now ignite your kindling, and from there the hearth twigs. This is a good quick fire, and can become a bigger one if you add more fuel. Other fire layouts may be better for purposes such as heating, however.

FIREMAKING'S THREE SIDES

Making fire requires three ingredients, sometimes shown in a triangle: oxygen, heat and fuel. Fire is a chemical process, primarily involving carbon in the fuel and oxygen from the air. The third element, heat, puts in energy to start breaking chemical bonds in the fuel and oxygen and making new ones, producing carbon dioxide. That process releases more heat, and now the fire can sustain itself.



FINDING YOUR WAY

If your tools get lost, nature can keep you on track

If your vehicle breaks down, or if you get off the track you were following, you need to find your way to your destination. Ideally you would have a map and compass and a device with GPS, but in the worst case scenario you might not even have that. How could you get to a safe place?

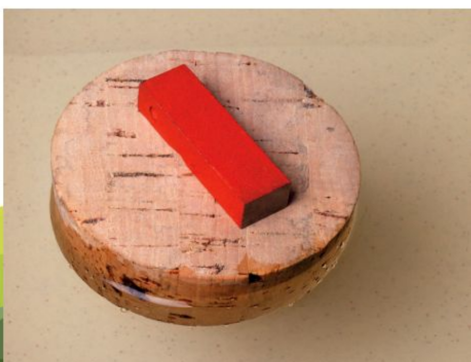
Throughout the history of humanity, we've used the Sun and stars to navigate by. If you know that the Sun rises in the east and sets in the west, and that the Sun is due south at its highest point, you can in principle follow a straight line out of the wilderness. Using the stars, you can look for the pole star in the Northern Hemisphere and the Southern Cross in the Southern Hemisphere. Landscape features can also act as guides. Streams, rivers and lakes can help stop you going back on yourself.

MAKE YOUR OWN COMPASS

KIT LIST

- **Sewing needle**
- **Circle cut from cork**
- **A shallow bowl**
- **Pliers**

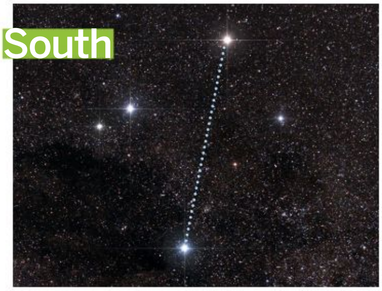
Rub the magnet from one end of the needle to the other a few times. Grip the needle with the pliers, and push it through the curved side of the cork. Push until you can see the same length of needle poking out of both ends. Fill the bowl with water, and float the cork on top. Put the bowl on a flat surface, and watch it align with magnetic fields. You can now take it outside and align yourself on a map.



DID YOU KNOW? Shivering means you are cold, but stopping can be worse – your body may have fallen below 32 degrees Celsius

STARS LIGHT THE WAY

Find the well-known Big Dipper asterism in Ursa Major. If you consider that this looks like a saucepan, follow a straight line from the vertical handleless side of the pan to the North Star.



The Southern Cross is relatively easy to see, with its four stars arranged like a crucifix. The longer line of the crucifix points towards the South Pole. Confusingly, there is another cross nearby, but that one has five stars.

TOP TIP!

STEERING BY THE SUN

In the daytime, you can find your way using the Sun. Find a stick that's about a metre long and fix it vertically into the ground. Place a stone on the tip of the stick's shadow. Wait at least ten minutes, and then place another stone at the tip of the stick's shadow. The line between the stones will point directly from east to west, the second stone at the east end, and the first stone at the west end.

KEEPING YOURSELF FED

Nutritious food can often be found alongside the bad

Hunger is another of the many discomforts the wilderness brings. It comes when our energy levels are low. In emergency situations, most humans will be able to survive for short periods by eating 500 to 800 calories per day. However, if you are in very hot or cold conditions, regulating your body temperature will use up more energy than normal.

Humans have long hunted animals as a wild food source, but you may not have the skills to do this and there might not be any around. You can eat some insects, and there are many plants to eat. But not every plant is edible – if in doubt, don't eat it. If a mouthful of plant burns or irritates the mouth, it should not be swallowed, but this can't always be relied upon.

EATS AND DON'T EATS

What plants to look for and what to avoid in five different environments

EDIBLE

ICELAND MOSS
MOUNTAINS
This is a highly nutritious food source, but soak it and change the water twice before eating it.

MESQUITE TREE
DESERT
Beans of this tree are edible, and young, soft bean pods can be cooked and eaten like green beans.

MANGO TREE
JUNGLE
If you get lost in the jungle, you can hopefully find many familiar nutritious fruits like mangoes.

GREEN SEAWEED, OR 'SEA LETTUCE'
ISLAND
The sea is full of edible sea lettuce, used in sushi. It's high in protein and fibre.

WILD GARLIC
FOREST
With a distinctive smell, this vitamin-rich leafy plant with small white flowers can be abundant.

TOXIC

JIMSONWEED
DESERT
This has large white or violet trumpet-shaped flowers. All parts of the plant are poisonous to humans.

YELLOW OLEANDER
JUNGLE
These flowers contain milky sap, which must be avoided as it's highly poisonous.

CASTOR BEAN
JUNGLE AND ISLAND
While the castor bean is widely used in food, the outer covering of its bean is highly toxic.

FOXGLOVE
FOREST
Seeds contain the digitalis compound that makes your heart beat irregularly and makes you sick.

ARCTIC POPPIES
ARCTIC
With yellow petals and black hair, this plant is poisonous, but you can eat the leaves if you cook them.

© Getty / Alamy / Illustration Ed Crooks

HOW FIRESTORMS FORM

What do you get when you cross a fire with a tornado?

WORDS **CHARLOTTE HARTLEY**

Onlookers witnessed a fire tornado rising from the flames of the Pine Gulch Fire in August 2020 in Colorado

This apocalyptic-sounding phenomenon occurs when a fire grows large and angry enough to sustain its own weather system. Fierce heat, mixed with turbulent whirlwinds, creates a tornado-like vortex. It sucks ash, embers and flammable gases up into the air, forming a swirling tower of flame called a fire whirl, but also frequently referred to as a fire tornado. These are not considered true tornadoes, however. Unlike a tornado, the vortex of a fire whirl rarely extends all the way from the ground to the clouds, and they form differently.

The most impressive fire tornadoes are forged from wildfires, where they typically reach between 10 and 50 metres in height. Some are born in the plume of a volcanic eruption. Fire whirls are usually transient, fluttering into existence for only a few short minutes before swiftly dying. There are exceptions though: in the Carr Fire of California in 2018, a monstrous three-mile-tall 'firenado' blazed for almost an hour.

Unsurprisingly, these fiery spectacles can be a force of destruction. Fire tornadoes can blaze through natural forests and human-made settlements alike. Sometimes the intense winds lift up burning materials and spit them out elsewhere. This is called 'spotting', and it helps wildfires spread.

Fire tornado formation is relatively rare; it relies on a precise balance of extreme temperatures and rapidly changing wind speed or direction. But as a warming climate and poor fire management practices increase the frequency of large wildfires, these conditions could be met more easily in future.

Did you know?
These tornados are usually two to ten metres in height

A fire tornado blazed through the town of Peshtigo in 1871, destroying everything in its path

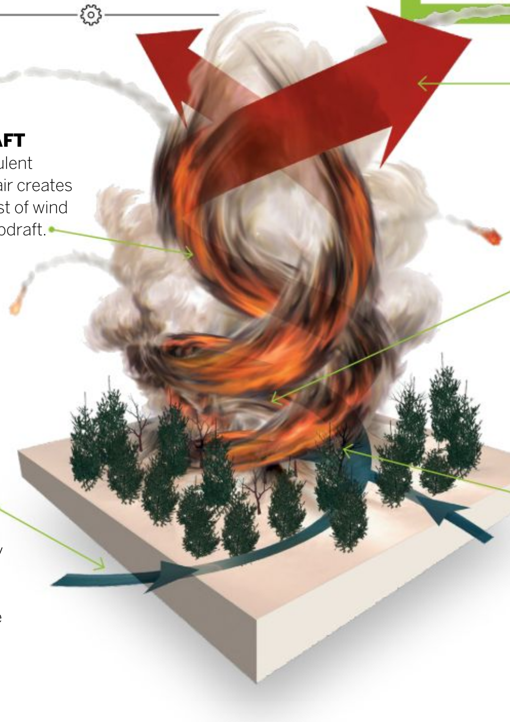
THE PESHTIGO FIRESTORM

On 8 October 1871, a vast inferno swept through the community of Peshtigo in Wisconsin. The fire burned around 1,200,000 acres of land and killed between 1,500 and 2,500 people. But despite it being America's deadliest wildfire in recorded history, many people have never heard of the Peshtigo Fire. It has been largely overshadowed by the more famous Great Chicago Fire, which occurred on the same day.

An unusually dry summer season had triggered a few smaller and manageable wildfires in the area. But then strong winds from the west fanned their flames, blowing the fires out of control into a devastatingly destructive firestorm.

HOW DOES A FIRE WHIRL FORM?

These fiery whirlwinds require a precise combination of weather conditions



UPDRAFT
The turbulent movement of air creates a powerful gust of wind called an updraft.

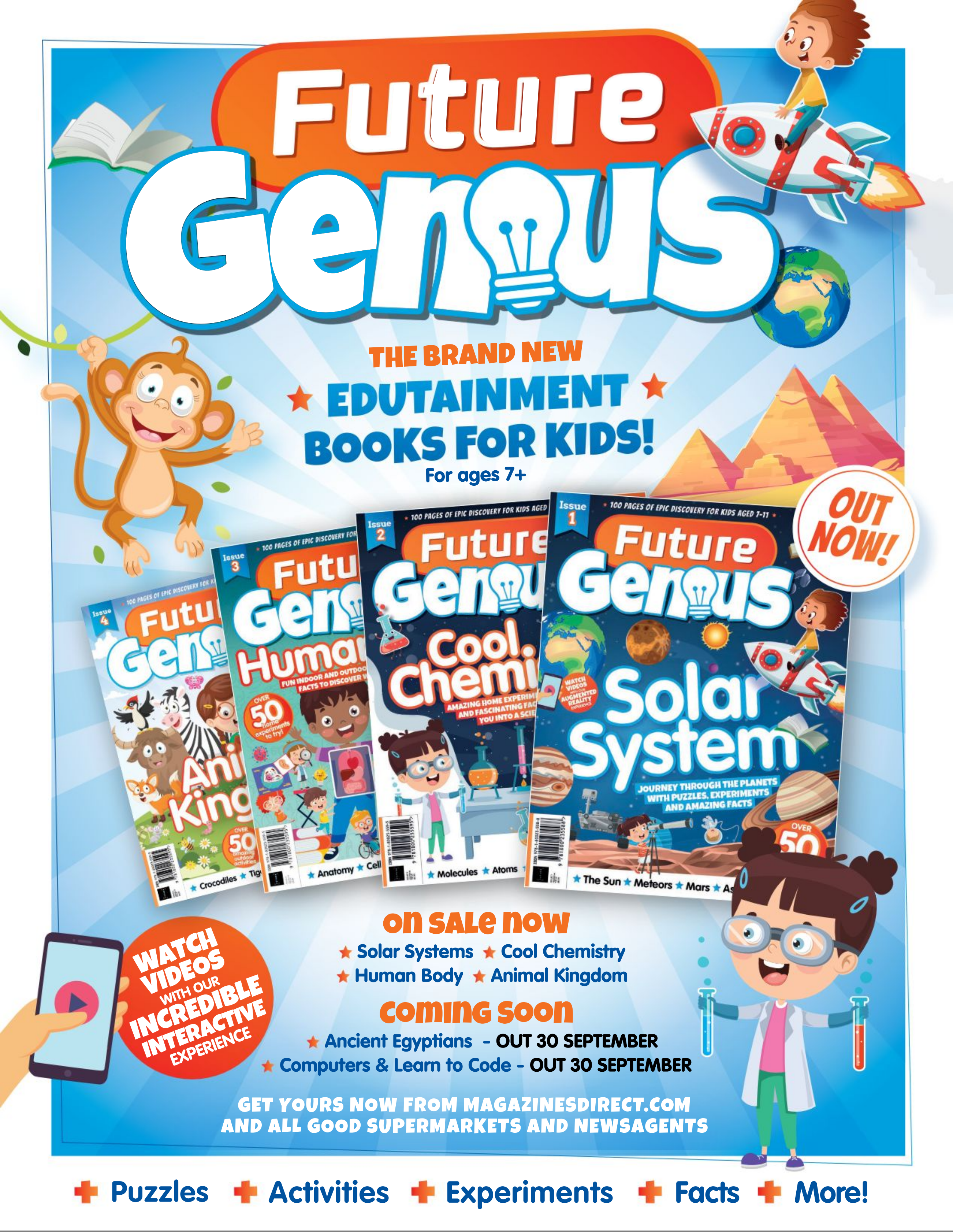
FIRE WHIRL
Embers and ash from the wildfire get caught in the wind, swirling the fire up into a tornado-like whirl.

HEAT RISES
Fire heats the air around it. Gases expand as they warm, so the hot air becomes lighter and floats upwards.

VACUUM
Rising hot air leaves an empty space called a vacuum. Air surrounding the fire rushes in to fill the void.

WILDFIRE
Wildfires can occur naturally due to lightning strikes or lava flows. But the vast majority are caused unintentionally by people.

© Alamy / Science Photo Library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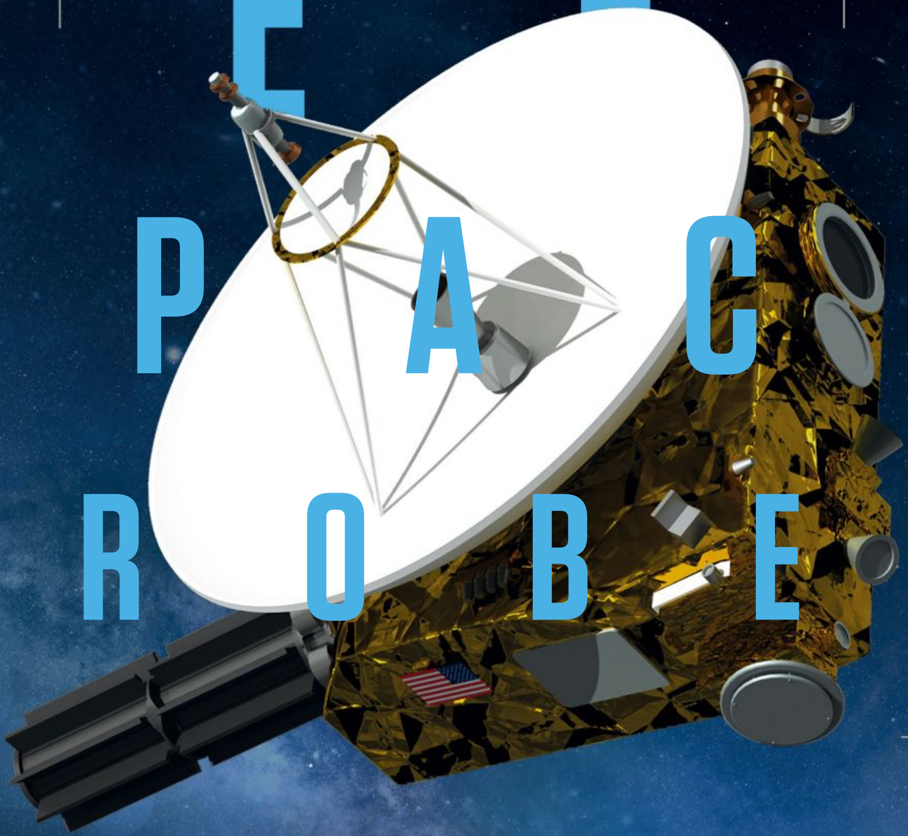
DEEP SPACE PROBES



Five of NASA's long-range spacecraft are heading beyond the Solar System. What will they find?

WORDS ANDREW MAY

When NASA's Cassini mission to Saturn ended in 2017, the spacecraft was deliberately destroyed by crashing it into the planet. The next year, at the end of the Dawn probe's exploration of the asteroid belt, it was placed in a graveyard orbit around the dwarf planet Ceres. These are the two most common fates of interplanetary missions, but there's a third possibility. If a probe has sufficient speed to carry it out of the Solar System and into the space between stars, it can keep travelling forever.

Five probes have ended up on interstellar trajectories so far. Although their designers knew this would happen, it wasn't their main purpose. The first four – Pioneer 10 and 11, and Voyager 1 and 2 – were launched in the 1970s to study the Solar System's outer planets. More recently they've been joined by New Horizons, launched in 2006 en route to the Kuiper Belt, where it flew past Pluto in 2015 and Arrokoth in 2019.

Pinning down the edge of the Solar System isn't easy. By some definitions it might include the Oort Cloud, which surrounds the Sun at a great distance. By common convention, however, 'interstellar space' starts at a point called the heliopause. This is where the Sun's non-gravitational effects – its magnetic field and the solar wind – cease to be discernible against the background of the interstellar medium.

Voyager 1 passed this point in 2012, followed by Voyager 2 in 2018. The other three probes will follow over the next few decades, although we don't know exactly when, as the heliopause tends to drift about in an unpredictable way.

DID YOU KNOW? Five of the scientific instruments on Voyager 2, and four on Voyager 1, are still functioning today

Voyager 1 & 2

THE GRAND TOUR

> "Five probes have ended up on interstellar trajectories so far"

The idea behind the Voyager project originated in 1964, when NASA scientists noticed that an unusual planetary alignment would occur in the late 1970s, allowing a single spacecraft trajectory to pass close to Jupiter, Saturn, Uranus and Neptune in turn. The gravitational boost acquired at each encounter would send the probe on its way to the next planet. Initially dubbed the 'Grand Tour', the mission went through various design changes as NASA struggled to match scientific aspirations to the available budget. In the end, two virtually identical spacecraft were launched: Voyager 2 on 20 August 1977, and Voyager 1 – on a faster trajectory which saw it reach Jupiter first – 16 days later.

Although the Grand Tour could have been completed with a single spacecraft, there were advantages in using two. First, it meant one of them could take greater risks. For example, Voyager 1 got twice as close to Jupiter, with its hazardous radiation field, than Voyager 2, which erred on the side of caution. When Voyager 1 reached Saturn, NASA also wanted to explore its intriguing moon Titan. But this diversion prevented Voyager 1 from reaching Uranus and Neptune – a task that was left for Voyager 2.

The 'Pale Blue Dot' – Voyager 1's iconic photo of Earth from 3.7 billion miles away

VOYAGER'S GOLDEN RECORD

Knowing that the Voyagers would eventually venture out into interstellar space, NASA decided to include messages from Earth in case they were intercepted by another civilisation in the future. These take the form of old-style LP records, one on each spacecraft, made not from vinyl but gold-plated copper. They include greetings in 55 languages, a selection of natural 'sounds of Earth' and 27 music tracks from different cultures. The records also contain a selection of images, encoded in analogue form, while mathematical symbols inscribed on their covers explain how they are to be played.

Did you know?
Edward C. Stone has been Voyager's project scientist since 1972

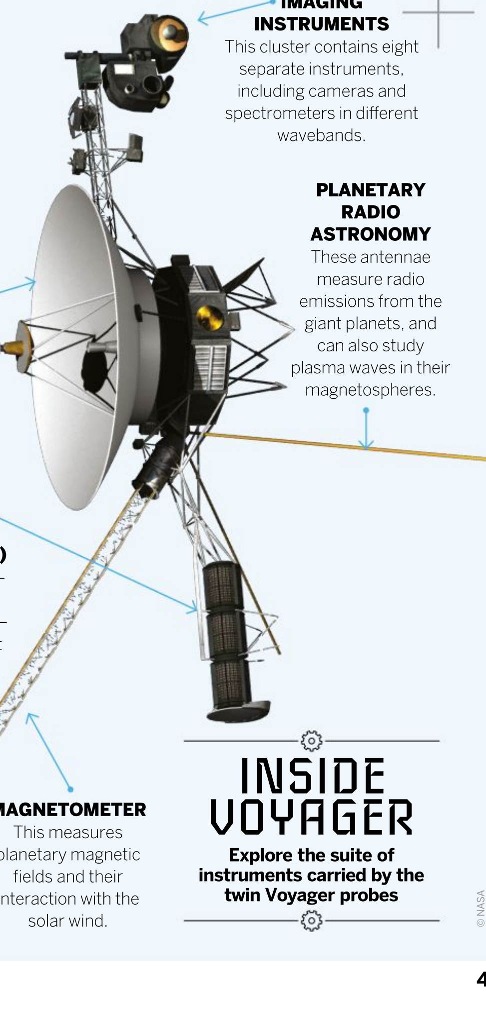
TECH SPECS

YEAR LAUNCHED: 1977

MISSION COST: $895 million

VOYAGER 1 DISTANCE TRAVELLED: 14.2 billion miles

VOYAGER 2 DISTANCE TRAVELLED: 11.8 billion miles



IMAGING INSTRUMENTS
This cluster contains eight separate instruments, including cameras and spectrometers in different wavebands.

PLANETARY RADIO ASTRONOMY
These antennae measure radio emissions from the giant planets, and can also study plasma waves in their magnetospheres.

HIGH-GAIN ANTENNA
This powerful dish antenna, 3.7 metres in diameter, is how the spacecraft sends data back to Earth.

RADIOISOTOPE THERMOELECTRIC GENERATORS (RTGS)
There are three of these – essentially batteries powered by radioactivity – to provide the spacecraft with electric power.

MAGNETOMETER
This measures planetary magnetic fields and their interaction with the solar wind.

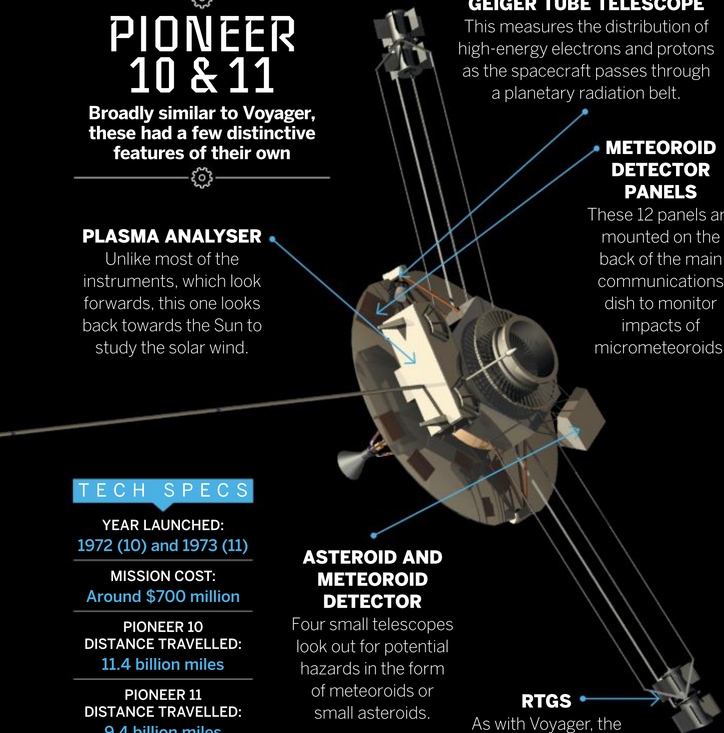
INSIDE VOYAGER

Explore the suite of instruments carried by the twin Voyager probes

© NASA

PIONEER 10 & 11

Broadly similar to Voyager, these had a few distinctive features of their own



GEIGER TUBE TELESCOPE
This measures the distribution of high-energy electrons and protons as the spacecraft passes through a planetary radiation belt.

METEOROID DETECTOR PANELS
These 12 panels are mounted on the back of the main communications dish to monitor impacts of micrometeoroids.

PLASMA ANALYSER
Unlike most of the instruments, which look forwards, this one looks back towards the Sun to study the solar wind.

ASTEROID AND METEOROID DETECTOR
Four small telescopes look out for potential hazards in the form of meteoroids or small asteroids.

RTGS
As with Voyager, the Pioneers are powered by radioisotope thermoelectric generators, this time four of them on two separate booms.

TECH SPECS

YEAR LAUNCHED:
1972 (10) and 1973 (11)

MISSION COST:
Around $700 million

PIONEER 10 DISTANCE TRAVELLED:
11.4 billion miles

PIONEER 11 DISTANCE TRAVELLED:
9.4 billion miles

Pioneer 10 & 11 PAVING THE WAY

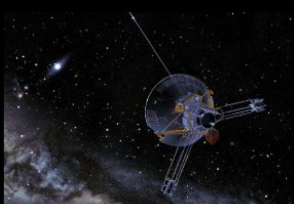
NASA's Pioneer program, which ran for two decades from 1958 to 1978, involved a series of custom-built spacecraft designed to test out various aspects of spaceflight beyond Earth orbit. Two of these spacecraft, Pioneers 10 and 11, acted as pathfinders for the Voyager project, with both having a focus on spaceflight engineering as much as planetary research.

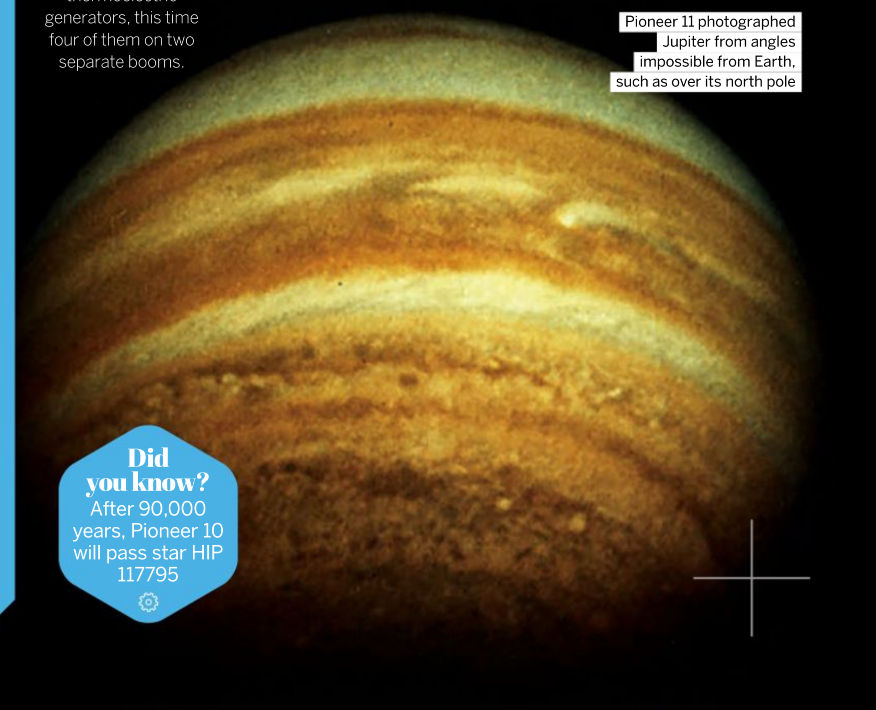
Pioneer 10 was launched in March 1972, reaching the asteroid belt – the first spacecraft to do so – in July that year. It crossed it unscathed, since it isn't as hazardous as it's often portrayed in fiction, and reached Jupiter in December 1973, capturing the first close-up images of its atmosphere and moons. As it passed by, Pioneer 10 used the slingshot effect of Jupiter's gravity to boost it onto an interstellar trajectory. It was the first spacecraft to employ a 'gravity assist' manoeuvre of this type, and the first to acquire escape velocity from the Solar System.

Around a year after its predecessor, Pioneer 11 followed in its footsteps – but with an added twist. As well as acquiring escape velocity, the boost it received from Jupiter put it on course for a flyby of Saturn, which took place in September 1979.

PIONEER ANOMALY

One of the remarkable things about long-distance spaceflights is how accurately they can be modelled on a computer. Once clear of Earth, the main force acting on craft is gravity, which behaves in a highly predictable way. It came as a surprise when scientists found Pioneer 10 and 11 were slowing down more quickly than expected from the Sun's gravitational pull. Some thought this indicated a problem with our understanding of gravity, but NASA traced the 'Pioneer anomaly' to an asymmetry in the way they radiated waste heat.





Pioneer 11 photographed Jupiter from angles impossible from Earth, such as over its north pole

Did you know?
After 90,000 years, Pioneer 10 will pass star HIP 117795

New Horizons
TO PLUTO AND BEYOND

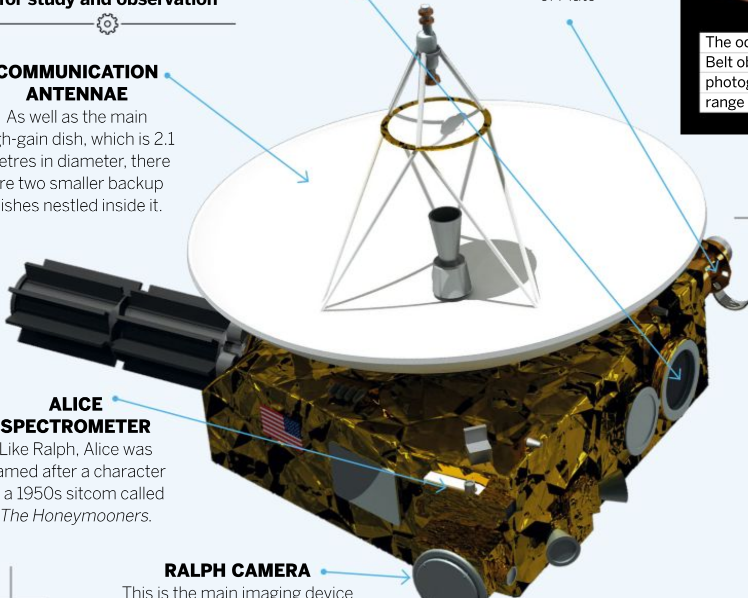
> "It would leave the Solar System faster than any spacecraft to date"

While the Pioneer and Voyager missions focused on the four giant outer planets, New Horizons whizzed past these with barely a glance. Its area of interest lay farther out, in the Kuiper Belt. This distant region of the Solar System, beyond the orbit of Neptune, was hardly known to astronomers when the earlier probes left Earth, but has attracted increasing attention since. For decades the only known Kuiper Belt object was Pluto, and this was New Horizons' first destination, which it reached in July 2015 after a journey of nine-and-a-half years.

A flyby of Pluto, rather than Saturn's moon Titan, had been on the cards for Voyager 1, but it lost out because it was expected to be a dead world. The images and data sent back by New Horizons proved how mistaken this was. With an atmosphere, geological activity and possible cryovolcanoes, Pluto is as fascinating as any full-blown planet. Three-and-a-half years after its Pluto encounter, New Horizons passed a second – and much smaller – Kuiper Belt object. Called Arrokoth, it's the most distant body to have been photographed at close range by a spacecraft.

TO NEW HORIZONS

New Horizons is crammed with scientific instruments for study and observation



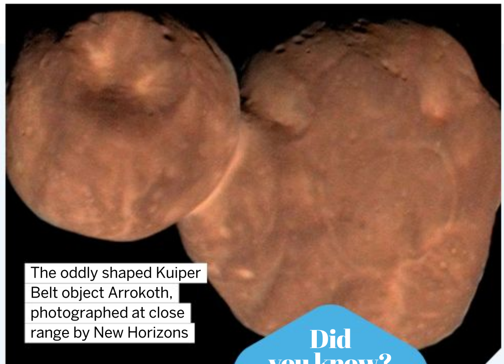
LORRI
The Long-Range Reconnaissance Imager is a 208-millimetre-aperture telescope used for preliminary studies of more distant objects.

PLASMA SPECTROMETER SUITE
These instruments are designed to study high-energy solar wind particles in the vicinity of Pluto

COMMUNICATION ANTENNAE
As well as the main high-gain dish, which is 2.1 metres in diameter, there are two smaller backup dishes nestled inside it.

ALICE SPECTROMETER
Like Ralph, Alice was named after a character in a 1950s sitcom called *The Honeymooners*.

RALPH CAMERA
This is the main imaging device on New Horizons, essentially a compact 75-millimetre-aperture astronomical telescope.



The oddly shaped Kuiper Belt object Arrokoth, photographed at close range by New Horizons

Did you know?
For economy, New Horizons reused parts designed for other missions

TECH SPECS

YEAR LAUNCHED: 2006

MISSION COST: $780 million

DISTANCE TRAVELLED: 4.6 billion miles

THE FASTEST SPACECRAFT

While the idea of a 'speed record' is clear enough on Earth, things become more complicated in space. Should a spacecraft's speed be measured relative to Earth, the Sun or whichever planet it happens to be closest to? And its speed during an interplanetary mission doesn't necessarily reflect how powerful its rocket engine is. It can also acquire significant speed boosts from the gravitational slingshot effect as it swings around planets without expending any energy at all. However, in terms of its initial speed as it left Earth – 36,373 miles per hour – New Horizons is the fastest spacecraft ever launched.

© NASA / Alamy

PLANNING THE NEXT MISSION

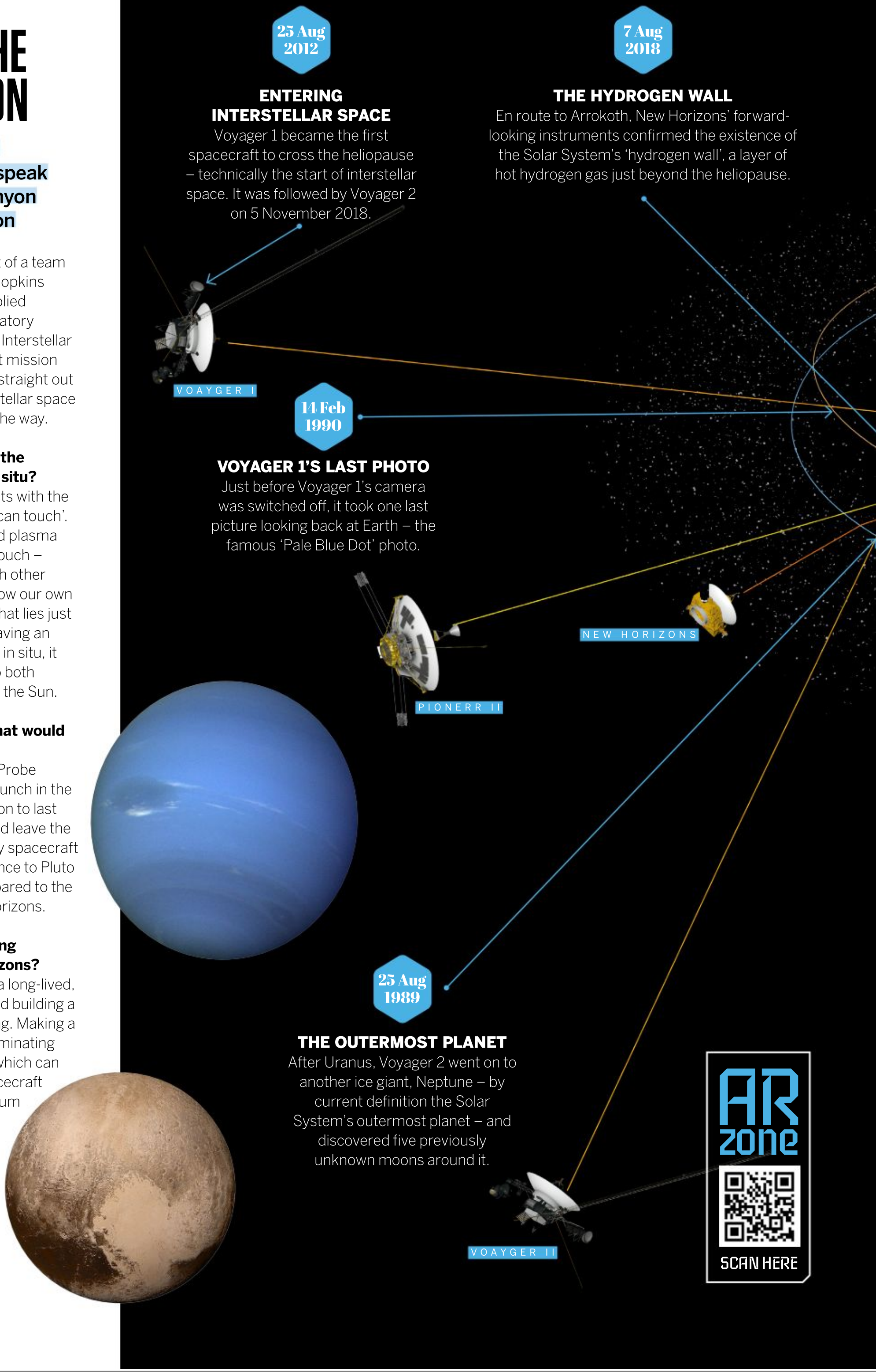
How about a dedicated interstellar probe? We speak with scientist Kirby Runyon about a far-flung mission

Runyon is part of a team at the Johns Hopkins University Applied Physics Laboratory working on an Interstellar Probe concept mission that would fly straight out to study interstellar space without visiting any planets on the way.

Why is it important to study the interstellar medium (ISM) in situ?
Finding out how the Sun interacts with the ISM in situ is 'astrophysics you can touch'. To understand the gas, dust and plasma that we can observe – but not touch – surrounding and interacting with other stars, we need to understand how our own Sun's 'weather' is affected by what lies just beyond the Solar System. By having an interstellar probe study the ISM in situ, it will be providing ground truth to both astrophysics and the physics of the Sun.

If the project goes ahead, what would the timescale be?
If NASA selects the Interstellar Probe concept, we would hope for a launch in the early 2030s on a 50-year mission to last into the 2080s. Because it would leave the Solar System far faster than any spacecraft to date, it would travel the distance to Pluto in only about four years – compared to the almost ten years it took New Horizons.

What are the main engineering challenges beyond New Horizons?
The biggest challenge for such a long-lived, 50-year mission is designing and building a spacecraft that can last that long. Making a long-lived spacecraft means eliminating and reducing moveable parts, which can wear out, and ensuring the spacecraft has enough power from plutonium batteries to last that long. The Voyager craft were designed to last four years, but they've both been operating since 1977 – 44 years! But designing a spacecraft to last multiple decades is very different from a spacecraft 'accidentally' lasting that long.



DID YOU KNOW? After its last encounter, Voyager 2 is diving downwards at 48 degrees relative to the plane of the planets

1 Sep 1979

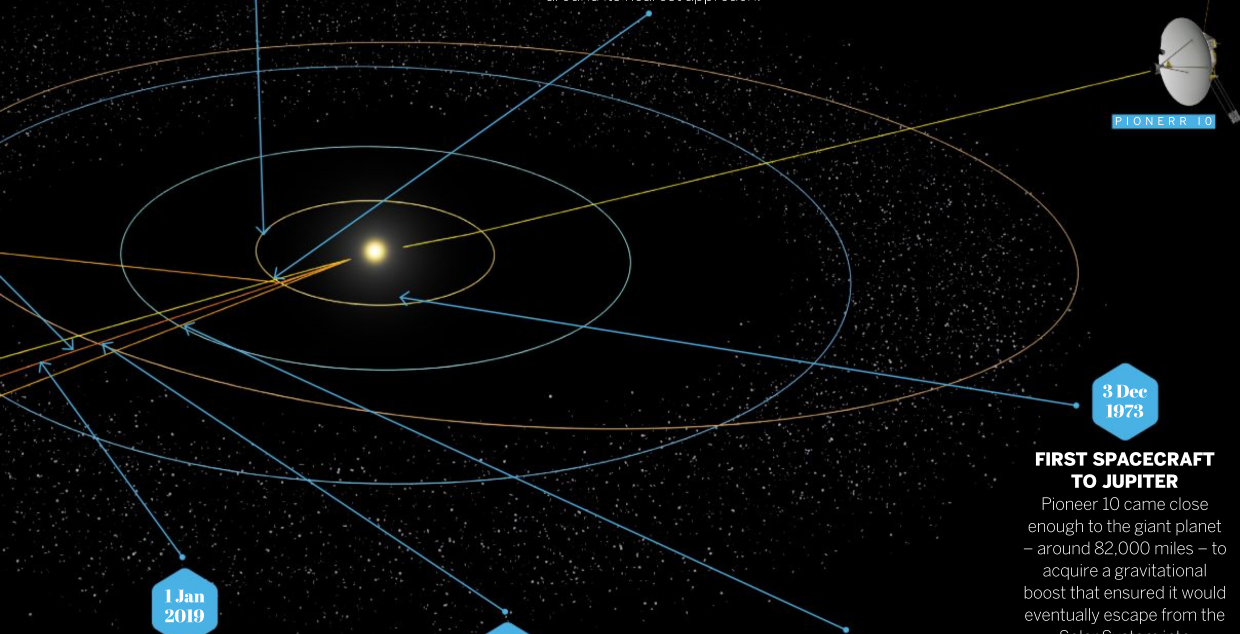
INSIDE SATURN'S RINGS

Pioneer 11 flew past Jupiter too, but it then went on to the next planet out, passing within 13,000 miles of Saturn, well inside the planet's rings.

12 Nov 1980

EXPLORING THE SATURN SYSTEM

Voyager 1 also visited Jupiter and Saturn, but with much more sophisticated instruments than Pioneer, taking spectacular close-up images of the ringed planet and its moon Titan on and around its nearest approach.



3 Dec 1973

FIRST SPACECRAFT TO JUPITER

Pioneer 10 came close enough to the giant planet – around 82,000 miles – to acquire a gravitational boost that ensured it would eventually escape from the Solar System into interstellar space.

1 Jan 2019

ARROKOTH ARRIVAL

New Horizons' next encounter after Pluto was with a much smaller Kuiper Belt object, known at the time as 2014 MU69, but since named Arrokoth.

14 Jul 2015

NEW HORIZONS AT PLUTO

The closest of the dwarf planets in the Kuiper Belt, Pluto was seen in breathtaking detail when New Horizons passed within 7,770 miles of it.

24 Jan 1986

THE RINGS OF URANUS

Voyager 2 was the first probe to reach Uranus, the icy seventh planet, and captured the first clear images of its faint ring system.

NASA'S DEEP-SPACE MISSIONS

Before heading out of the Solar System, the five probes achieved some impressive firsts

KEY

- Saturn
- Uranus
- Neptune
- Pluto

Saturn,taken by Voyager 1 on 18 October

The rings of Uranus, taken by Voyager 2 on 22 January 1986

© NASA / Johns Hopkins APL / Illustration by Adrian Mann


European Astronaut Corps
esa
esa
european astronaut corps
Timothy Peake

DID YOU KNOW? Peake completed around 3,000 orbits of Earth during his first mission on the ISS

MAJOR TIM PEAKE

The European Space Agency astronaut speaks to **How It Works** about his time on the International Space Station, life in the universe and careers in space

INTERVIEWED BY **BEN BIGGS**

As a test pilot in the British Army Air Corps, Major Tim Peake's service was star-studded. Anyone would have excused him if he had rested on his laurels when he retired in 2009, but it was only then that his career took off – literally. He became the first British person to visit the ISS in 2015 after being selected for the ESA's astronaut training program. He was the first British person to perform a spacewalk outside the ISS, and was the first man to run a marathon in space – on a treadmill, of course.

What was your first thought as you left Earth's atmosphere?
The first thought - I guess it's kind of relief, that you made it safely. Not that we expected it to go wrong, but actually there are many delays and problems. The first thought as you make it into orbit is a look between the crew members to think 'yes, we're here. We made it'. And then it's a look outside the window. Absolutely phenomenal, that view of Earth from space. And certainly as a rookie astronaut looking at it for the first time is amazing. The sense of speed is unbelievable during third stage, as the rocket is getting you up to 27,500 kilometres [17,088 miles] per hour – ten times the speed of a bullet. And you don't notice that the first couple of stages in launch are all about power acceleration. It's about 9 million horsepower, doing four gs of acceleration, so eight minutes and 48 seconds is a long launch period. But the latter stage is just about acceleration getting knocked off orbital velocity. So when you take that first look outside the window, you can't believe how fast you're covering the planet's surface.

Were you able to see London's M25 motorway from space?
What's interesting is nighttime. You see all of the lights of human habitation, so yes, you see the M25 at night, but you don't see it in the daytime. It's startling, the difference between day and night. In daytime it's incredibly hard to see any signs of human habitation as you look at planet Earth. If you're passing by, it might escape you that there's any human life down there at all. But at night it's so obvious to see.

What was the coolest experiment you carried out in space?
There are loads of really cool experiments. We're looking at metal alloys, which are really cool. We also did some combustion experiments. Normally we don't like to set fire to things in space, but we were actually looking at how a flame propagates in a weightless environment. This is looking at combustion techniques which could help our efficiency of combustion engines down on Earth, so that was a really exciting experiment. Another one we used was using the air lock to actually reduce the pressure, looking at airway inflammation. This is something that's going to help asthma sufferers back down here on Earth. And we had to go to quite a low pressure in the airlock. That was actually the first time we'd used the airlock as an experiment.

"It could be catastrophic if it hit the space station. It could destroy it"

Opposite: Peake made his space debut on Expedition 46 to the ISS

Left: Peake stands next to the Russian Soyuz craft that took him into space

© Alamy

Why did Luca Parmitano's spacesuit fill up with water?
That's a question that we pondered for a long time. It's a serious incident, so the suit had to be sent back down to Earth, where it was stripped down and analysed. It was a component separator that had failed, where we carry a lot of water in the spacesuit that's used for our cooling system. Interestingly, we don't have any heaters. A lot of the thermal extremes on a spacewalk are quite remarkable. You go from 150 degrees Celsius in the Sun to -150 degrees Celsius in the shade – you can have one arm working in the shade and one arm working in the Sun – and your suit's having to deal with that temperature differential, so we carry a lot of water. Water is designed to keep us cool, and our body heat is the only thing that generates the heat to keep us warm. That water system goes into a block that's exposed to the vacuum, freezes and forms an ice block. And that ice block there is how the water then runs across the ice bath and keeps us cool. That water-cooling system should never get into the ventilation system. But there's a part there that removes the moisture from the air that we're breathing out, and that broke. Basically, water from the cooling system was being pumped directly into the ventilation system, and the ventilation system's exit point is to the back of the head, so it was coming straight into the helmet. Now the maintenance is done much more routinely and much more regularly.

"If you're passing by, it might escape you that there's any human life down there at all. But at night it's obvious to see"

Is there anything you've learned from travelling in space about what humankind is doing to the planet?
Interestingly, when you go to space over a six-month period, it's hard for us to see any long-term impacts of climate change. But when you see the photographs that we've been taking over 20 years from the space station, you can see clear evidence of the impact that we're having. You can see evidence of climate change in terms of the volume of ice in the Antarctic, and the Arctic as well. You can see mass areas of deforestation, and you can see glacial retreat. And what we do see on the space station routinely, when we fly over very populated areas, is large amounts of smog and atmospheric pollution. On the southern part of the Himalayas, for example, it's a completely brown slate of smog. On the Tibetan side it's crystal clear; it's a very stark illustration of what impact humans are having.

The other thing I think really strikes you as an astronaut is when you see every sunrise and sunset – we get 16 of them a day, plenty of sunrises and sunsets. There are a few moments where you can see the curvature of the Earth, and you see how thin the atmosphere is. It's about 16 kilometres [9.9 miles] thick, so it's tiny. And that's what really brings it home, thinking wow, you know, that's what makes it different to Mars and Venus. It's just that thin layer of gas that protects all life on the planet.

When you see wildfires in Canada or California, you see how the smoke was spread over the entire continent of North America, or you see a sandstorm in the Sahara and see it spread out from France and Portugal to the UK, it again highlights just how thin that atmosphere is. Our pollution, whether it's natural in terms of forest fires or sandstorms, or whether it's human-made, it doesn't have much room to move, it has to spread out. We're all breathing the same air, and I think that's the biggest impact on you that you have as an astronaut.

Do you see space travel going electric?
Absolutely. There's all sorts of different methodologies being investigated. Ion thrusters, for example, we're looking at that as a slow but steady form of acceleration for a mission on a spacecraft. We're looking at solar sail technology as well, and even laser-based technologies – using lasers to actually assist with rocket thrust. We're looking at all sorts of different technologies as to how you can minimise the amount of carbon required to get objects into space.

Rockets take up a huge amount of energy, but if we can do it from a single stage to launch – something like the way Reaction Engines are trying to build this SABRE engine – the entire spacecraft will be able to land with no jettisons, a complete single-station launch, which will be an absolute game changer. So yes, the space industry is working towards that.

How much does orbital waste impact space mission?
It's becoming a lot more frequent. We have this thing called a debris avoidance manoeuvre, and we used to have to do a debris avoidance manoeuvre about once or twice a year five years ago. Now we're doing it five or six times a year because

Above: In space, the gravity-driven convection that colours the flame yellow with soot is absent, so a candle's flame is spherical and blue instead

Below left: A view of the Alps and the Mediterranean as Peake passed over on Expedition 46

we leave so much more debris. The space station is protected with armour plating from anything up to about a centimetre, and our ground radars can track things from about three centimetres upwards. We have [pieces of space junk] between one and three centimetres where it could be catastrophic if it hit the space station. It could destroy it, and yet we can't see it. It's definitely a big risk for the space station.

Is there intelligent life out there?
I think when you look at it statistically, the Kepler space telescope has now found at least 5,000 habitable planets in our own Milky Way. And that's searching any incredibly small patch of the universe. When you magnify that to the probability of habitable habitats in the rest of our galaxy alone, it runs into potentially hundreds of thousands, if not millions. Then when you look at what we're capturing in space, these micrometeorites have got organic compounds in them. We know that the building blocks of life are scattered around in meteorites and asteroids. Water is prolific throughout the Solar System. We know it's on every planet – pretty much – and it's in asteroids and meteors.

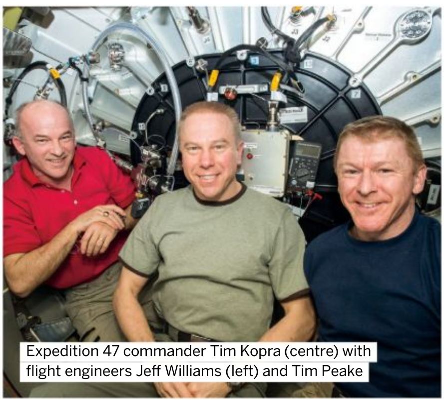
There's plenty of water, habitable planets and you've got the building blocks of life, so the chances of biogenesis happening on another planet are frankly huge. Then you've got a big leap from single-celled life forms to complex life – and I think that is a big leap. I think intelligent life is probably much rarer. But I think it's absolutely bound to be out there somewhere. And even if it's only one per galaxy, which is incredibly conservative, then there are a hundred billion galaxies.

What career route would an aspiring astronaut need to take?
In just my class of astronauts, in the European corps of astronauts, we've got schoolteachers, we've got medical doctors, we've got engineers, we've got scientists... We do have test pilots as well, but it's about 50 per cent.

Becoming an astronaut is going to be really interesting at the moment because the ESA's current selection process just closed a few weeks ago, and the selection will now go on for the next year before we choose at least four more astronauts into our corps, and I suspect they'll probably be fewer than 50 per cent military and military pilots.


Peake after being retrieved from his landing capsule

AR zone
SCAN HERE


Expedition 47 commander Tim Kopra (centre) with flight engineers Jeff Williams (left) and Tim Peake


Peake on one of the many extravehicular activities conducted by crews on the ISS


Italian astronaut Luca Parmitano's helmet filling with water

DROWNING IN SPACE

On 16 July 2013, ESA astronaut Luca Parmitano was on a routine spacewalk outside the ISS when his helmet began to fill with water. Approximately 1.5 litres of the stuff floated in under microgravity from a faulty cooling system in his suit, filling his eyes, nose and ears. The spacewalk was aborted, and Luca was brought back inside the ISS just in time. He later described it as being like "a goldfish inside a fish bowl". The crew's training kicked in and disaster was averted, but it caused quite a stir down on Earth as NASA looked into the precise cause of the fault and how to remedy it.

© ESA / NASA / Alamy

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MEET YOUR TEETH

How these pearlescent facial features develop and are maintained in a healthy mouth

WORDS **JAMES HORTON**

Your teeth offer so much more than just a winning smile. Alongside your tongue and saliva, teeth are integral for mastication, which is the process of breaking down food that enters the mouth into a bolus – a chewed ball of food – fit for swallowing. Teeth are also surprisingly complex components. They are formed of many layers, are organised into various functional shapes and erupt from the gumline at structured times during our development.

Teeth are supported in the mouth by the jawbone and gums, which surround and protect the lower features of each tooth. Teeth are not attached directly to the jawbone, but are linked to it via a strip of tissue known as the periodontal ligament. This ligament acts as a shock absorber for the jawbone, helping to ensure comfort when a tooth is exerting pressure on food and other teeth.

The periodontal ligament is connected to a thin layer of cementum, which provides a protective outer layer for the tooth's root. Encased within this layer, the horseshoe-shaped root sits embedded in the bone, helping to keep the tooth locked in place. As well as this, the root plays host to the pulp canals – a network of blood vessels and nerves that carries nutrients and signals to the rest of the tooth. The pulp canals coalesce into a pulp chamber above the root, but in healthy teeth the pulp chamber remains unseen, as it is covered by a protective sheath.

The immediate barrier surrounding the sensitive pulp is called dentin, which forms the largest bulk of the tooth. Formed of many tiny tubes, dentin is hard, but remains vulnerable to agents of decay. The outermost layer of the tooth, which forms the visible surface known as the crown that we see when looking at a healthy set of teeth, is formed of enamel. Enamel is almost entirely composed of unliving crystals containing calcium and phosphate, and in adult teeth it is the hardest substance of the body.

ERUPTION

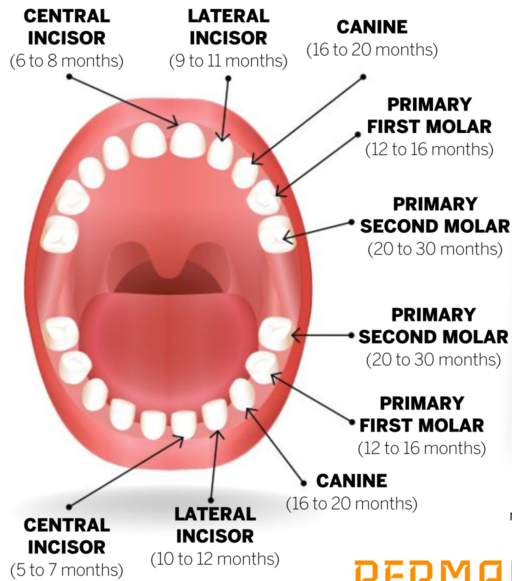
Humans, like our ape cousins and many other mammal species, are diphyodonts. This means we have two sets of teeth: an initial 'baby', or deciduous set, and an 'adult' permanent set that follow. In humans, the phases of growth in our teeth offer many advantages. The delayed eruption of our first teeth allows mothers to nurse more comfortably. And replacing the smaller deciduous teeth with larger, permanent teeth as a child ages accommodates the rapid increase in head and jaw size that occurs as we mature.

Most permanent teeth are in place by the age of 13, as these teeth erupt from underneath the deciduous set and dislodge them. However, wisdom teeth – also known as the third set of molars – do not appear until early adulthood, if at all. Wisdom teeth play a modest role in assisting with mastication, and so offer little advantage to the modern human. Due to the lateness of their arrival and the limited space available in the gumline, wisdom teeth can also unsettle the other molars and cause pain and discomfort. As such, many adults have their wisdom teeth removed, and others never get them, leading to the idea that humans may be evolving away from a third set of molars.

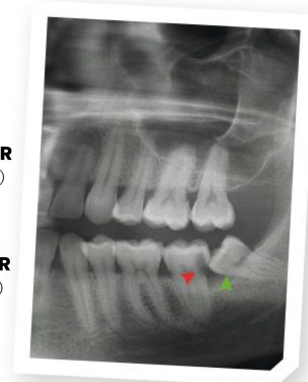
Permanent teeth form beneath the gumline during development and push deciduous teeth out on their way to eruption

DECIDUOUS

Your first set of teeth erupt from the gums at around six months old



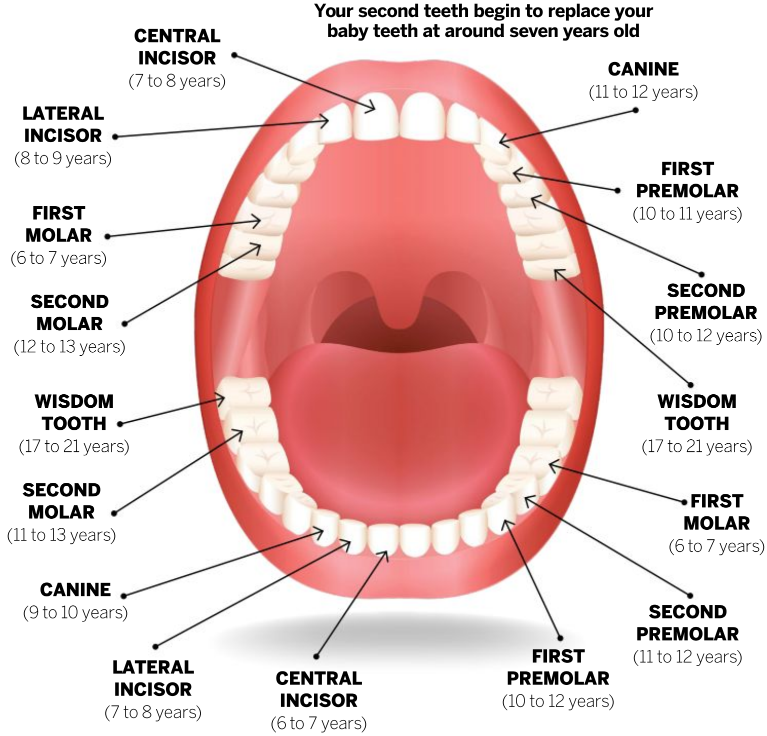
"Teeth are supported in the mouth by the jawbone and gums"



The eruption of wisdom teeth can be partially or totally blocked by other molars, a process known as impaction

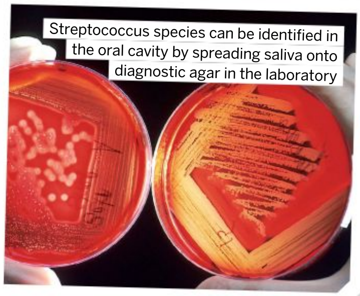
PERMANENT

Your second teeth begin to replace your baby teeth at around seven years old



© Getty / Alamy

BUILDING PLAQUE AND TARTAR



Streptococcus species can be identified in the oral cavity by spreading saliva onto diagnostic agar in the laboratory

Your teeth and gums are under constant threat from other residents of the oral cavity

As the hardest substance in the human body, with a composition of mostly hardy minerals, a tooth's outer enamel surface is well equipped to handle wear and tear. This is especially important, as permanent teeth in humans are, as their name entails, intended to be a permanent feature. There are no natural replacements available to us if we lose a tooth. However, food itself is not the only threat to the integrity of our teeth, because our mouths are by no means unoccupied. They are home to hundreds of different bacterial species, together numbering in their billions. These tiny microorganisms may be invisible to the naked eye, but they can wreak more havoc on our oral health than the largest and toughest piece of food.

Just as great, sturdy mountains are eventually toppled by a multitude of tiny erosions, so too can the hard surface of enamel be eventually worn away by the swarm of bacteria residing in the oral cavity. Bacteria's primary ability to achieve this erosion is through the formation of plaque. Bacteria feed on the food we eat just as we do, and readily metabolise sources of energy such as sugar and carbohydrates to create harmful acids. This cocktail of compounds and microorganisms can then fuse to form a type of biofilm – colloquially referred to as 'bacterial cities' – known as plaque. If left unchecked, plaque can readily harden into a calculus, also known as tartar, which is much more difficult to remove and yet more damaging to teeth and the gumline.

> "This cocktail of compounds and microorganisms fuses to form a 'bacterial city' known as plaque"

But the human body is not without natural defences designed to mitigate bacterial damage to the oral cavity. After all, for much of human history we have been without the means to properly clean and look after our teeth with dental brushes, toothpaste and flossing tape.

Fortunately, our saliva contains a battery of compounds that help keep bacteria in check. The

DARK HISTORY OF DENTISTRY

Although ancient civilisations didn't feast on as many plaque-inducing foodstuffs as we do in modern times, people still suffered tooth problems. This meant that the occupation of dentistry came into existence thousands of years ago, although at its outset was mostly useless.

Roman scholar Pliny suggested a cure for toothache could be found by imploring a frog to cure you by moonlight. Scribonius Largus offered a more reasonable suggestion, including washing the mouth with hot water, but the effectiveness of this was likewise limited. If a tooth needed to be removed, ancient dentists wrestled them free with forceps made from bone or boxwood.

Barber surgeons were a one-size-fits-all medical practitioner and groomer – they regularly pulled teeth in the UK until the mid-18th century

THE CHEMISTRY OF PLAQUE

How bacteria residing in the oral cavity utilise your dinner to form a plaque paradise

1 DINNER TIME Colonising bacteria utilise energy from ingested sugar, available in the oral cavity, to lay the foundation of plaque.

2 SETTING THE STAGE The colonisers produce molecules known as glucosyltransferases (GTFs), which facilitate the production of cavity-causing, or cariogenic, plaque.

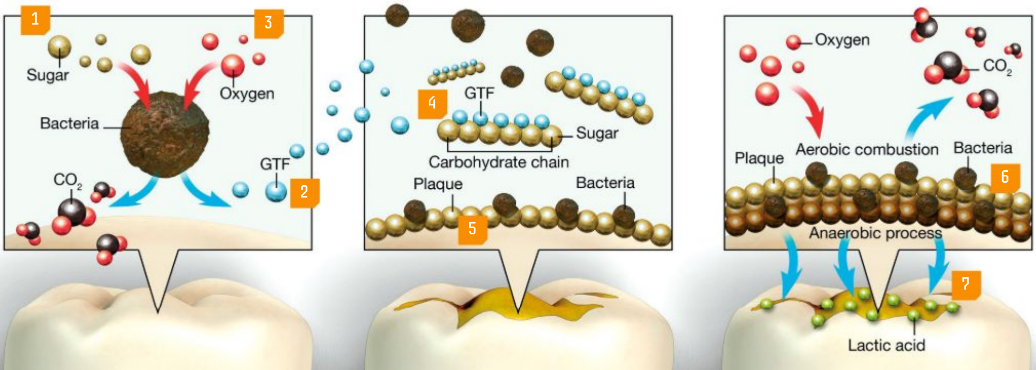
3 EXPOSED Prior to producing a biofilm, bacteria are readily exposed to oxygen and so can undergo aerobic – or oxygen-utilising – processes.

4 COMING TOGETHER GTFs perform numerous functions, binding both to sugars and other bacteria for incorporation into plaque.

5 ASSEMBLY Colonising bacteria and some GTFs stick to the enamel surface, while other GTFs break sugar into glucans, which then also join the budding matrix.

6 UNDER COVER As the plaque expands, the encased bacteria are separated due to oxygen exposure, creating an anaerobic environment.

7 ACID TEST Deep within the biofilm, against the enamel, bacteria undergo anaerobic respiration, creating lactic acid as a by-product, which erodes the tooth.



amylase enzymes dissolve carbohydrates in the mouth, denying bacteria a bounty from a piece of food lodged between two teeth. Additionally, mucins glycoproteins adhere to bacteria and remove them from surfaces where they can be harmful. However, in many modern societies, saliva alone is not enough to combat bacterial proliferation. Modern diets are laced with carbohydrates and sugars that were considerably more scarce for our hunter-gatherer ancestors, and the rate of tooth decay has increased as a result. We also produce less saliva when we sleep, because we spend a lot of time not chewing during the night, and this grants near free reign to our mouths' bacterial inhabitants. A testimony to the increase in bacteria while we sleep is halitosis, or 'morning breath', of which unchecked bacterial division is the primary cause. For many leading today's lifestyle, it's important that we regularly brush and floss to remove food debris and plaque before the latter hardens into calculus – especially before bed.

EARLY BACTERIAL COLONISTS

Both tooth decay and gum disease are predominantly owed to the activity of bacteria. The oral microbiome, which describes the bacterial community that has taken residence in the oral cavity, is a diverse one, with over 600 species being present in some individuals. These bacteria first arrive in the mouth shortly after birth, where often a group of bacteria known as streptococcus spearhead the colonisation charge. Streptococci are adept at producing adhesive molecules, and so are well suited for establishing themselves across the different niches found in the mouth. They're also efficient metabolisers of carbohydrates, which they achieve via a process of fermentation that creates harmful acids as a by-product.

Species from the genus Streptococci act as forerunners for establishing microbiomes in the oral cavity

STAGES OF TOOTH DECAY

How bacterial erosion gnaws away at the integrity of the tooth

1 A PROTECTIVE COATING
In a healthy tooth, the vulnerable network of blood vessels and nerve endings, and the softer dentin bulk, are protected by enamel on the crown and cementum at the roots.

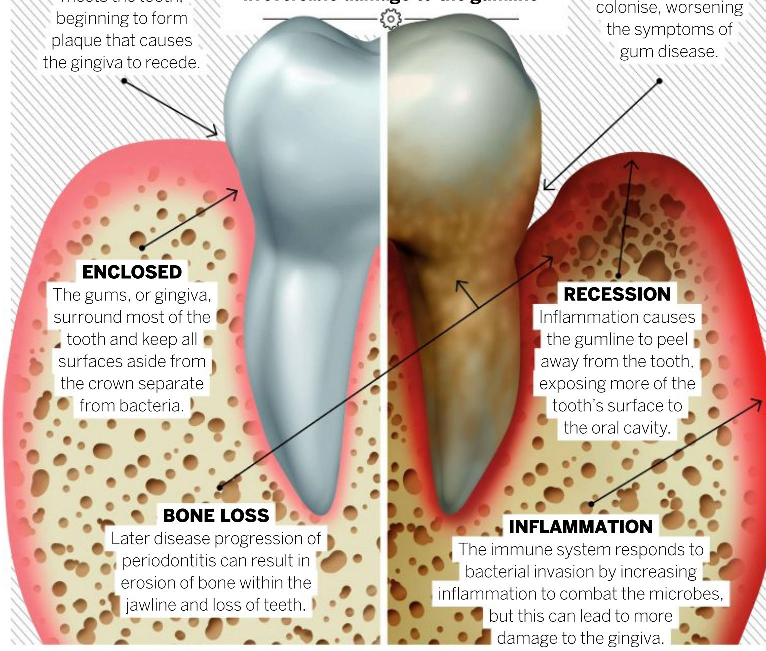
2 ESTABLISHMENT OF PLAQUE
Bacteria, food debris and a sweep of small molecules aggregate into a biofilm known as plaque. Over time plaque hardens into calculus, which is difficult to remove.

3 EROSION
Harmful acids produced by colonising bacteria slowly wear away at the hard mineral structure of the enamel, making contact with the softer and more sensitive dentin underneath.

4 INFECTION
Once bacteria chips through the dentin it arrives at the pulp, a sensitive bundle of nerves and blood vessels. This often results in a serious infection which can destroy the tooth.

PERIODONTAL DISEASE PROGRESSION

The progression from mild gingivitis to periodontitis can cause irreversible damage to the gumline



© Getty / Alamy / WikiCommons Bill Bransen

DENTAL REPAIRS

A trip to the dentist can fix many oral issues

Despite our best efforts, sometimes teeth and gums require professional treatment. With gums this usually involves cleaning via a process known as a scale and polish, where a dental hygienist will use specialised tools to remove calculus that has accumulated on the teeth and around the gumline. For people with periodontal issues, calculus can build up even when following a rigorous oral hygiene regimen. Therefore routine visits to the hygienist are essential for keeping gum disease at bay.

There are a plethora of treatment options available for teeth. When erosion occurs, the tooth becomes susceptible to infection, requiring the use of fillings to seal the breach point and protect the tooth from further damage. If the infection has made its way into the pulp and the blood supply has become infected, however, a more invasive treatment is required. Known as a root canal, this process involves physically removing bacteria from the root by removing the pulp from the tooth, then filling in the cavity with composite materials.

For people who've had their teeth broken, knocked out or removed because of infection or disease, there are also now many forms of replacement teeth. Some of these, such as veneers and crowns, attach to a part of the natural tooth, though in both cases the tooth is sometimes carved down to a point before attachment. When the natural tooth is completely missing, treatments such as bridges or dental implants, which involve drilling the replacement tooth into the jawbone, can be used to affix permanent replacements.

Above: Hygienists use specialist tools to remove hardened calculus, which cannot be removed easily at home

Top: Some types of dental implant involve drilling the replacement tooth directly into the jawbone

Did you know?
Sharks typically lose at least one tooth per week

FILLING MATERIALS

AMALGAM

1 Made of a metal mixture containing mercury, silver and others, these have been used by dentists for well over 100 years. They are durable fillings that can protect a tooth over multiple decades.

COMPOSITE

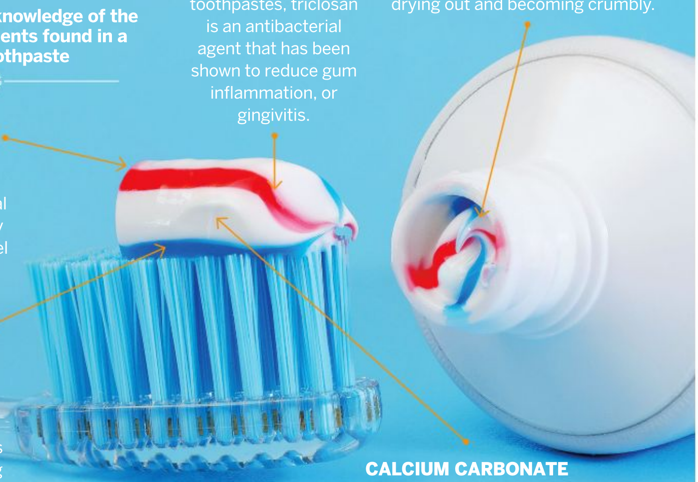
2 Although not as hardy as amalgam or gold, composite fillings are made from a combination of ceramic particles and are tooth-coloured, allowing a filling to appear more organic.

GOLD

3 Unlike composites and amalgam, gold fillings are made in laboratories following dental impressions. Although more expensive and labour-intensive, gold fillings are strong and do not tarnish, allowing them to last for many years.

THE INGREDIENTS OF TOOTHPASTE

Scrub up on your knowledge of the common components found in a tube of toothpaste



TRICLOSAN
Only used in marketed antimicrobial toothpastes, triclosan is an antibacterial agent that has been shown to reduce gum inflammation, or gingivitis.

SORBITOL
As a natural sweetener and humectant, sorbitol adds both sugar-free flavour to the toothpaste and helps prevent it from drying out and becoming crumbly.

SODIUM FLUORIDE
Fluoride is the key component of most toothpastes. This mineral helps prevent cavities by strengthening the enamel on your teeth.

LAURYL SULPHATE
Detergents help toothpaste become foamy as you brush. This is important for ensuring dispersal of the toothpaste so it can efficiently coat the teeth.

CALCIUM CARBONATE
Abrasive components such as calcium carbonate are used to remove surface stains and small pieces of debris from the teeth.

KEEPING CLEAN

A handy guide to help you stay on top of your dental hygiene

BRUSHING

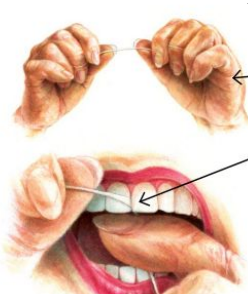
CHECK YOUR ANGLE
Hold your toothbrush at a 45-degree angle as you perform gentle and short back-and-forth motions.

SCRUB THE CROWNS
Firmer flat back-and-forth motions can be used for cleaning crowns, as the toothbrush will not meet the gumline.

BE GENTLE TO GUMS
Maintain the 45-degree angle when trying to clean your gumline, as this will help prevent excessive abrasive contact that can cause recession.

DON'T FORGET THE BACK
Use gentle up-and-down strokes to clean the backs of your incisors.

FLOSSING



ANTI-PLAQUE
Floss can be gently raised slightly above the gumline, permitted no resistance is met, to ensure plaque is removed.

TIGHT GAPS
Gently work the floss between teeth with small gaps using a see-sawing motion, then use an up-and-down motion to remove plaque and debris.

5 FACTS ABOUT TEETH

1 INCISORS ARE TROUBLEMAKERS
Lateral incisors can suffer from a spectrum of defects, such as missing enamel, a duplication of the tooth or an absence of the tooth. This is a consequence of how they develop in the jaw.

2 VERSATILE JAW MUSCLES
The muscles of the jaw generate the most power when compressing teeth vertically. However, humans can also shift their jaw forwards and side to side to assist compression chewing with sheer force.

3 TWO SETS ISN'T ENOUGH
Unlike mammals, other animals such as reptiles and toothed fishes boast polyphyodont dentition, which means they constantly replace their teeth until their tooth buds are completely depleted.

4 ADDITIONS, NOT SUBSTITUTIONS
Although deciduous back teeth are known as 'molars', their permanent successors are premolars. Permanent molars are additional teeth that only appear once the jaw is large enough to accommodate them.

5 TEETH ARE FOR TALKING
As well as helping us mechanically break down our food, teeth are also important for speech. Teeth are especially important for making 'F', 'V' and 'Th' sounds.

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INCREDIBLE ICE

We know that it's solid water, but that's just the tip of the iceberg

WORDS **CHARLOTTE HARTLEY**

Our 'blue planet' is famed for its expansive oceans and salty seas, but approximately ten per cent of our planet's surface is frozen over. The vast majority of this ice is found in the polar regions. The Antarctic ice sheet covers an area about the size of the United States and Mexico combined. Meanwhile, in the North Pole, the Greenland ice sheet is so heavy that it presses the land below into a concave bowl shape. Because of its bright-white colouration, ice reflects sunlight back into the atmosphere. This process plays a crucial role in regulating Earth's climate.

But icy worlds also exist beyond our own planet. When NASA's MESSENGER mission glimpsed bright spots at Mercury's poles, scientists theorised that water ice could be hiding inside the planet's deep, sunless craters.

Ice is simply the solid state of liquid water, forming at temperatures of zero degrees Celsius or below. Its chemical composition is two hydrogen atoms bonded to a single oxygen atom – also known as water.

Above main: The islet of Nordaustlandet in the Arctic Circle is covered by large ice caps

Above inset: A glacier is a giant mass of ice that travels slowly over land

When water is cooled to a low temperature, bonds form between different water molecules very easily. This forces water into a crystal lattice structure of many layers of hexagonal rings. Most elements are less compact in their liquid state. However, the unique hexagonal structure of ice crystals is filled with more gaps than the disordered fluid structure of water, meaning ice is about ten per cent less dense than water.

It is this phenomenon that allows ice to float – either in the form of gigantic icebergs travelling across the Arctic Ocean or ice cubes in a refreshing drink on a hot day. In fact, ice's cooling properties are very handy. Before we had electric refrigerators, ice boxes were used to keep food cold and fresh. Ice can also reduce swelling and pain by reducing blood flow to injured body parts.

"Because of its bright-white colouration, ice reflects sunlight back into the atmosphere"

WHY DOES SALT MELT ICE?

When snow is on the horizon, you might have noticed large lorries spreading rock salt on the roads and pavements to prevent them getting slippery. But how does salt get rid of ice?

Icy roads tend to have a thin layer of water covering the ice. This liquid water melts the ice, while the ice simultaneously freezes the water. This balances out so that the amount of water and ice remains constant. But not once you add salt.

Salt is made up of positive sodium and negative chloride ions. These charged particles dissolve in water, disrupting the arrangement of water molecules and making it more difficult for structured ice crystals to form. This lowers the freezing point of water, meaning colder temperatures are required for ice to form. The ice on the ground can no longer freeze the water at zero degrees Celsius. However, the water can still melt the ice. Ultimately, this leads to less ice on the roads.

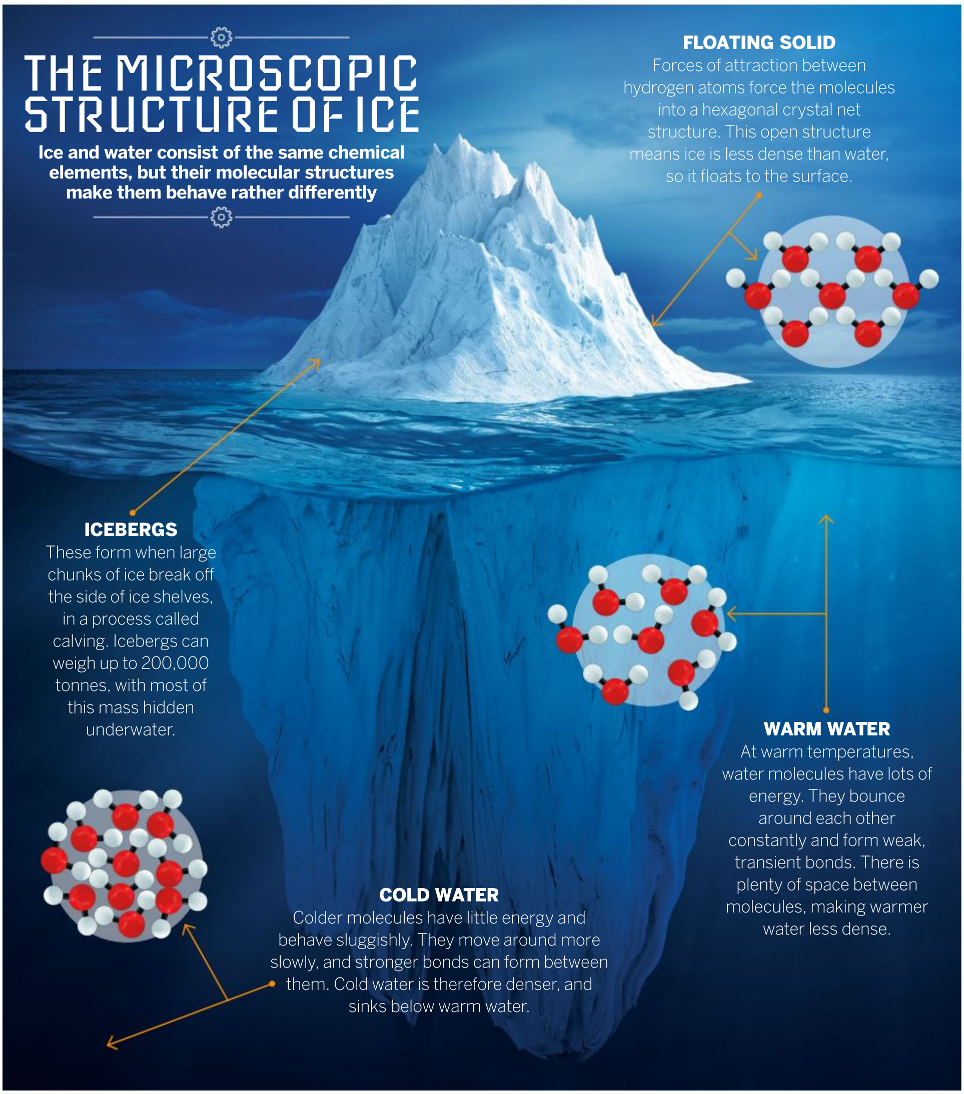
Tonnes of salt are needed every year to melt snow and ice

FLUFFY SNOW AND HARD ICE

As snow falls to the ground and forms a pile, tiny pockets of air become trapped in the empty spaces between individual snowflakes. This air gives snow its characteristic fluffiness.

If snow remains on the ground for a few days, more layers can build up. This crushes the lower layers, forcing air out and compacting the snow into a harder texture. If the snow then partially melts, droplets of water fill up the tiny spaces between snowflakes before refreezing into ice crystals. Eventually, almost no air is left inside the frozen layers, leaving a solid sheet of ice.


Snow gets its light and fluffy texture from air trapped between individual snowflakes



THE MICROSCOPIC STRUCTURE OF ICE

Ice and water consist of the same chemical elements, but their molecular structures make them behave rather differently

FLOATING SOLID

Forces of attraction between hydrogen atoms force the molecules into a hexagonal crystal net structure. This open structure means ice is less dense than water, so it floats to the surface.

ICEBERGS

These form when large chunks of ice break off the side of ice shelves, in a process called calving. Icebergs can weigh up to 200,000 tonnes, with most of this mass hidden underwater.

WARM WATER

At warm temperatures, water molecules have lots of energy. They bounce around each other constantly and form weak, transient bonds. There is plenty of space between molecules, making warmer water less dense.

COLD WATER

Colder molecules have little energy and behave sluggishly. They move around more slowly, and stronger bonds can form between them. Cold water is therefore denser, and sinks below warm water.

5 FREEZING FACTS

1 ICE IN SPACE
Far beyond our own Solar System, so-called 'interstellar ice' forms from frozen grains of space dust in dense molecular clouds where new stars are born.

2 BENDY CRYSTALS
Scientists invented a new type of ice that can bend and snap back into shape without breaking. They do this by growing long, single ice crystals in incredibly low temperatures.

3 GLACIAL STORAGE
Over two-thirds of Earth's freshwater is stored in glaciers. Scientists estimate that global sea levels would rise by 80 metres if every glacier and ice sheet melted.

4 ICY ERUPTION
On Enceladus, one of Saturn's moons, 'cryovolcanoes' eject ice instead of magma. Heated ice below the surface erupts as water vapour, turning into ice particles when exposed to the frosty atmosphere.

5 A HUNDRED NAMES FOR ICE
The Alaskan Inupiaq people have over 100 names for different types for ice. We have plenty of words in English, too, including bummock, hummock, floe and pancake ice.

© United States Geological Survey / Alamy / Getty

CARBON: THE MULTI-TOOL OF ELEMENTS

From thick and grimy oil to gleaming diamonds, carbon can take on many roles

WORDS **ANDY EXTANCE**

Carbon turns crystalline under great amounts of pressure

With a pencil, we can draw a picture of how useful the element carbon is. A pencil's lead is not the poisonous metal of the same name. Instead it's pure carbon, in a form known as graphite. In graphite, sheets of carbon atoms stack up in layers. When we write in pencil, we're leaving behind carbon sheet after carbon sheet. On their own these sheets are called graphene, which is very strong and special in many other ways.

The wood around the graphite lead also contains many carbon atoms connected with atoms of other elements, most importantly hydrogen. Our fingers are made of the same types of atoms as wood, but are soft and spongy, unlike the hard pencil materials. Combined with other atoms like this, carbon is found in all living things. It's also in fossils of things that lived long ago, both as carbonate rocks like chalk and as fossil fuels like natural gas, crude oil and coal. And when crushed inside the Earth, carbon forms beautiful diamond gems. All these different forms make carbon very important. Humans use it to make many things, including plastic. We can turn rocks into sturdy iron metal and even stronger steel metal alloys, also with carbon.

Fuel carbon burns, moving vehicles and generating electricity. When burning, carbon atoms combine with oxygen atoms from the air, making the greenhouse gas carbon dioxide. In small amounts this keeps Earth warm enough for us to live here. But humans now burn too much, making the world too hot as a result.

However, plants suck carbon into their leaves and stems from carbon dioxide in air. So having enough trees to pull carbon from the air is very important. Even cutting some trees down to put carbon in your pencil is better than burning wood and warming everything up.

Carbon from fossilised plants forms oil underground, which we bring up and use

Fossilised shells of tiny animals containing carbon form chalk, like in these cliffs

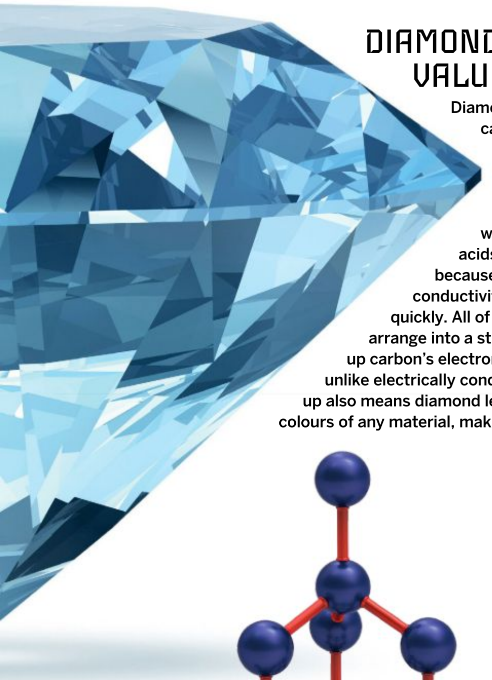
A HISTORY OF CARBON

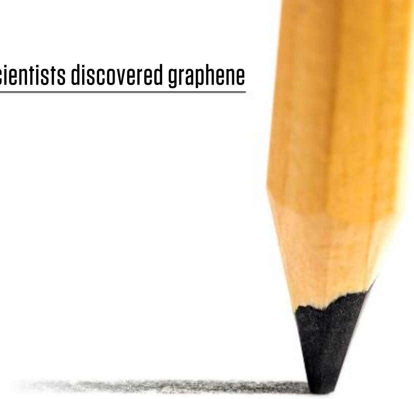
Even early humans knew about carbon, in the form of soot and charcoal. In ancient Rome the word carbo meant coal and charcoal, which is where the English word carbon comes from. Romans made charcoal by heating wood covered with clay to exclude air. We still do that in the same way now. Diamonds were probably first found around 4,500 years ago in China.

However, it's only in the last 500 years that people realised that all of these different forms were the same element. Diamond, being very hard and strong, was the most difficult to study. But in 1694 Italian scientists discovered that they could destroy diamonds with heat. They shone sunlight through a large magnifying glass onto a diamond, and the gem eventually disappeared. In 1796 an English scientist showed that diamond was a form of carbon because as it burns it forms only carbon dioxide.

Ancient charcoal ovens burned wood under clay to keep air out

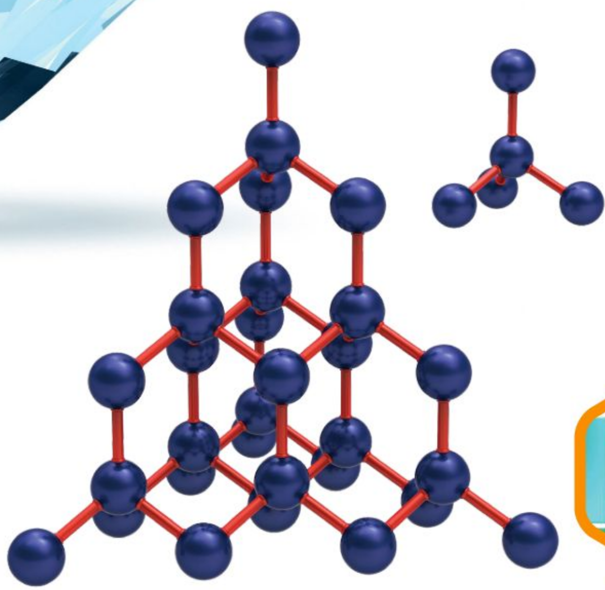
DID YOU KNOW? By sticking tape onto graphite and pulling off atom-thick carbon layers, scientists discovered graphene



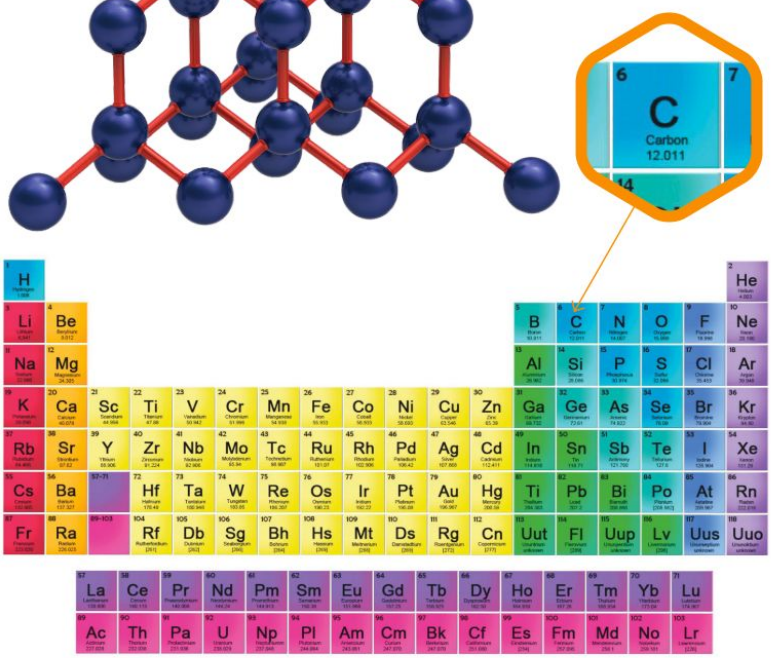


DIAMOND: BEAUTIFUL AND VALUABLE, BUT ALSO TOUGH

Diamond is more than the prettiest form of carbon; it's the hardest material known. Diamonds are made when carbon is crushed deep under the Earth's crust at temperatures over 1,000 degrees Celsius. Diamond is so tough it can withstand the strongest and most corrosive acids. Diamonds are always cold to the touch because they have the highest thermal conductivity of any material, channelling heat away quickly. All of this is thanks to the way carbon atoms arrange into a strong pyramid shape in diamonds. This ties up carbon's electrons, making diamond an electrical insulator, unlike electrically conductive graphite. Having its electrons tied up also means diamond lets through the broadest range of light colours of any material, making it beautifully clear.



A molecular model of carbon (right) next to a molecule of diamond, made up of a lattice of carbon molecules



CARBON IS EVERYWHERE

1 PETROL

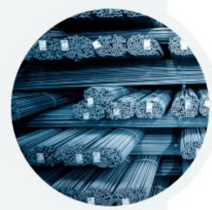
Carbon is useful because its atoms easily link together. They connect in many ways in crude oil, which is fossilised plant residue. We separate oil into different parts, one of which is the petrol we put into cars. Burning petrol in the engine releases energy to turn the car's wheels.

2 PLASTIC

We take molecules from oil and link them together in new ways to make plastics. This makes long, strong chains of carbon atoms. Plastic is easy to shape, and it's cheap, so we make many things out of it. However, plastic is hard to dispose of, which has become a problem.

3 STEEL

Mixing iron with carbon to produce steel can make a hard but relatively cheap metal alloy. It also reduces the chances of the metal produced rusting or breaking. Steel is used in many different industries, especially building and making cars.



4 MAKING DIAMONDS

Once, diamonds had to be dug up from underground. But scientists have found ways to make diamonds from hydrogen and methane, which comes from natural gas. At first these were tiny, hard, sharp diamonds that companies could use to make tools. But now they can make gems used in jewellery.

© Getty / Alamy

TECHNOLOGY

WHAT HAPPENS TO RADIOACTIVE WASTE?

Nuclear power is an amazing technology, but cleaning up after it isn't simple

WORDS ANDY EXTANCE

How do you store waste when its dangers could outlast the human species? It's a question we need to address after harnessing the awesome power of nuclear energy.

Nuclear fuel is usually a radioactive-enriched uranium pellet. About three atoms in every hundred are in a form called uranium-235. A uranium pellet is a small cylinder of uranium-235 about a centimetre long and wide. This nuclear pellet releases as much energy as burning a tonne of coal. Most often power plants use pellets sealed in fuel rods made of an alloy of the metal zirconium. Bundling rods together speeds up their radioactive decay in a chain reaction that releases heat. In power plants, these are covered in water. The steam that comes off drives turbines and generates electricity without releasing the greenhouse gas carbon dioxide, which is causing climate change.

The clues to the origins of the power and danger of nuclear energy are in its name. The laws of physics say when the nucleus at the heart of an atom is stable, and when it isn't. It's all down to the number of protons and neutrons in the nucleus. For example, in one form of uranium, the number of protons and neutrons means that the nucleus falls apart, or decays, easily. Part of the nucleus flies away as radiation, releasing energy as it does. When uranium fuel rods are bundled tightly together, the radiation from one rod triggers a uranium atom in a rod nearby to decay. That can then trigger another atom to decay, and another. Nuclear power plants are designed to keep this chain reaction going safely.

Eventually, the fuel rods release less energy, and then they must be replaced. But they're still very hot, and could be deadly if not handled carefully. A bundle of unshielded fuel rods could still release enough radioactive energy to kill you

Onkalo spent nuclear fuel repository in Finland is planned to store waste for 100,000 years

DID YOU KNOW? Nuclear waste can be moved by train in special cars called flasks, which protect the cargo from fire and leakage

With the rise of nuclear power came the need to dispose of waste products safely

"Uranium-235 in waste fuel rods makes them dangerous – and useful"

KNOW YOUR NUCLEAR WASTE

Not all types of nuclear waste are equally dangerous. Here are three of them

LOW-LEVEL WASTE

FORM
Produced by hospitals, industry and at nuclear energy sites, this includes paper, rags, tools and clothing.

STORAGE METHOD
This is pressed into a steel drum and kept underground in trenches or concrete vaults, but it can still be stored fairly near the surface.

INTERMEDIATE-LEVEL WASTE

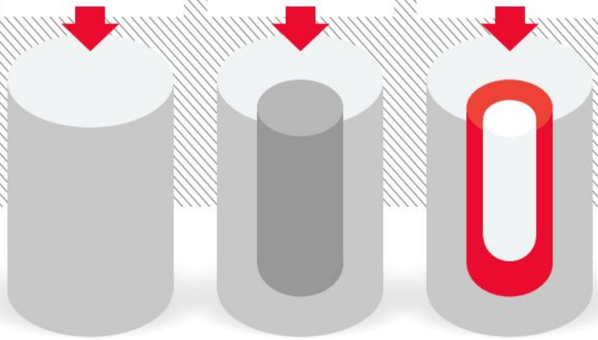
FORM
Fuel rod cladding, contaminated equipment and radioactive sludge that requires shielding.

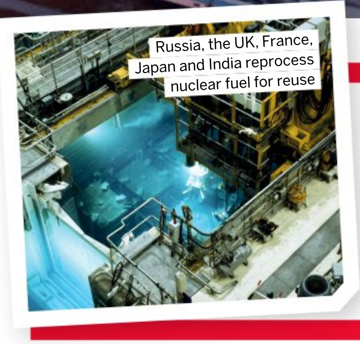
STORAGE METHOD
This is pressed into stainless-steel containers and encased in concrete, and is often stored in facilities similar to those used for low-level waste.

HIGH-LEVEL WASTE

FORM
Fuel rods from reactors and the waste left over after reprocessing them to reclaim radioactive uranium-235.

STORAGE METHOD
This highly radioactive material is mixed with melted glass, then poured into stainless-steel containers to solidify. Containers are buried up to 1,000 metres underground.





Russia, the UK, France, Japan and India reprocess nuclear fuel for reuse

WHO WANTS THE WASTE?

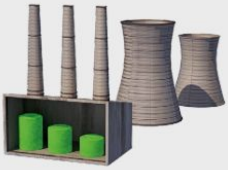
A landmark event for nuclear waste came on 2 December 1942, when scientists researching nuclear weapons in the US made the first nuclear reactor in a Chicago sports hall. By 1955 US scientists had recommended burying waste underground. But where could they put it?

The first American site chosen for high-level waste, in Lyons, Kansas, was rejected in the 1970s. In the 1980s the US chose Yucca Mountain, Nevada. But that was also rejected in 2009. In the meantime, some radioactive waste has been tipped into the sea. This largely stopped in the 1970s, and was completely abandoned by 1993. Because most radioactive waste still has valuable radioactive uranium in it, it's often recycled, not buried.

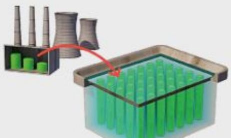
© Getty

BURYING NUCLEAR WASTE

High and low-level waste are stored in very different ways



1 MAKING HIGH-LEVEL WASTE
Radioactive uranium gradually decays so that it doesn't drive enough of a chain reaction, but it's still dangerous and hot.



2 MOVING IT TO A DIFFERENT POOL
Cranes move the uranium to a water-filled pool to cool down for five to ten years.

3 STORING IT SECURELY
The cooled uranium is secured in a steel container. It might be mixed with molten glass, and is also sometimes encased in concrete.

4 FINDING IT A HOME
Usually secured uranium has to travel to a storage site. Many countries don't yet have long-term storage for high-level waste.

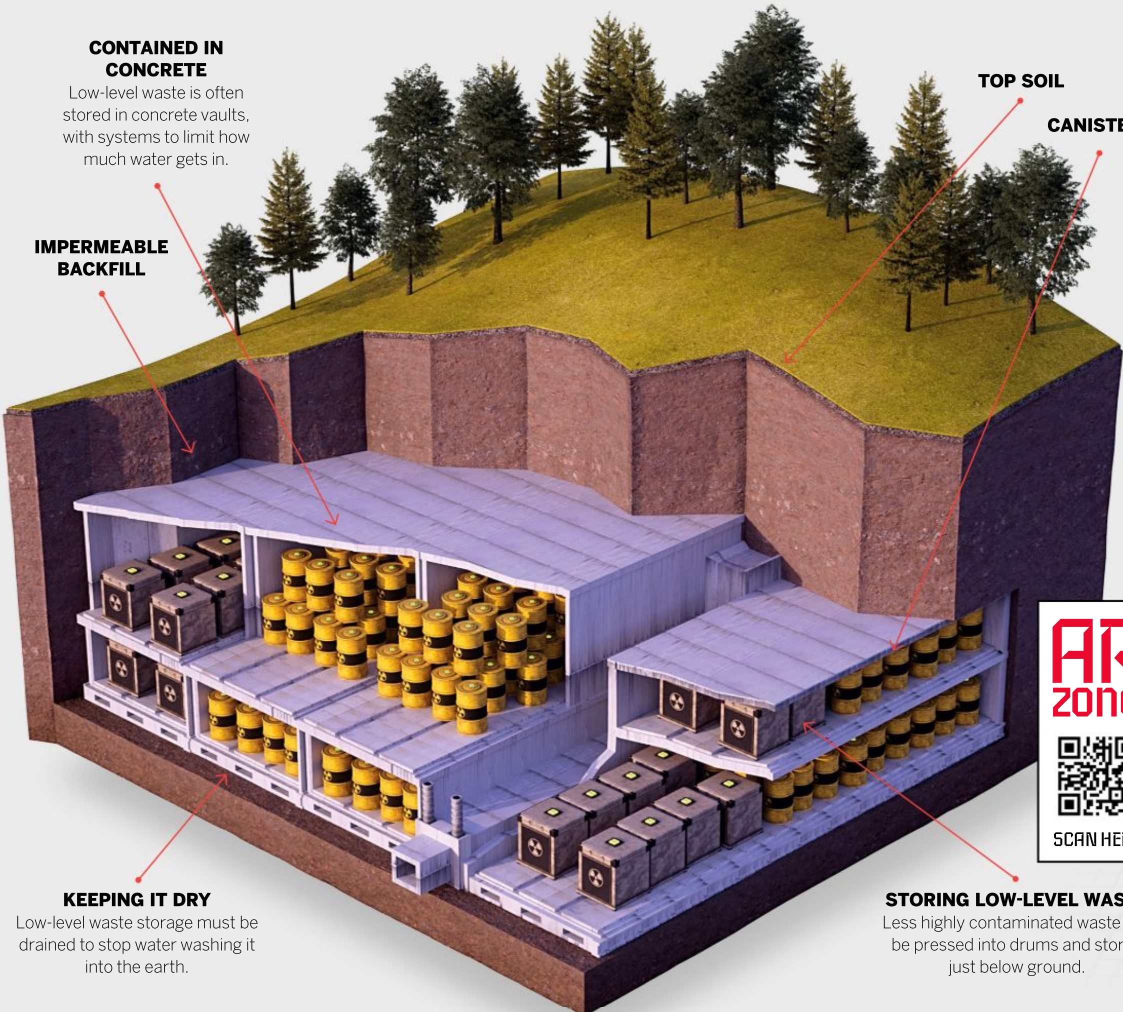
5 THE WASTE GOES DEEP
Properly stored high-level waste should be buried up to 1,000 metres underground.

CONTAINED IN CONCRETE
Low-level waste is often stored in concrete vaults, with systems to limit how much water gets in.

IMPERMEABLE BACKFILL

TOP SOIL

CANISTERS



KEEPING IT DRY
Low-level waste storage must be drained to stop water washing it into the earth.

STORING LOW-LEVEL WASTE
Less highly contaminated waste can be pressed into drums and stored just below ground.

AR zone

SCAN HERE

DID YOU KNOW? In 2005, seagulls were found to have been swimming in a pool filled with radioactive waste in Sellafield

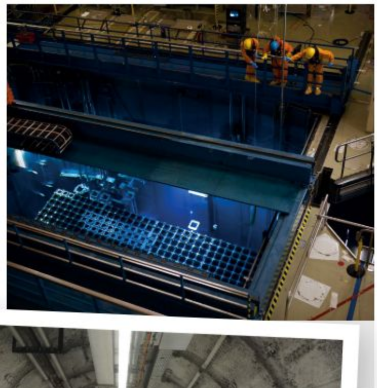
within hours. There are many radioactive substances in nature which in small amounts are safe, but in higher amounts they can be dangerous. The radiation that radioactive uranium releases can kill our cells by damaging our genetic material, or DNA.

Cranes, rather than people, usually handle radioactive materials straight from nuclear reactors. They pull spent fuel rods out of the reactor, keeping them under water or in another shielding liquid. They're usually kept in storage pools for a few years, with the water being kept topped up as the heat from the rods boils it off.

The world has more than 250,000 tonnes of high-level nuclear waste (HLW) that needs to be stored, with over 90,000 tonnes in the US. We add around 12,000 tonnes to this each year. Uranium-235 in waste fuel rods makes them dangerous – and useful. Some facilities reprocess the waste, removing remaining uranium-235 to put in new fuel rods. Yet even this process leaves some HLW behind. Usually all nuclear waste ends up in steel containers and buried underground. When stored, the danger from the waste initially falls quickly. The heat and radioactivity it releases when it leaves a reactor is about 100 times higher than what it will be after 50 years. However, it still takes HLW a long time to become truly safe. The Onkalo spent nuclear fuel repository is planning for it to take 100,000 years. For comparison, the oldest pyramid is just 4,600 years old. It's one of many ways that nuclear power has changed how we think.

Below: Nuclear fuel rods are stored underwater to keep them cool when they leave a reactor

Bottom: A low-level nuclear waste facility, safely storing LLW until it decays



ON THE MAP

Where some of the world's radioactive waste is stored

HOW RISKY IS NUCLEAR WASTE?

Professor Katherine Morris from the University of Manchester, UK, is a top nuclear waste expert

What's the easiest way to understand the problem of nuclear waste?
The UK has run nuclear reactors for about 60 years. We have wastes from power generation that are radioactive. Time will allow for radioactive decay to stabilise elements. You go from something radioactive to something stable. The international community, over the decades, has thought this one through. The outcome is that for the fraction of wastes that are most radioactive, you're best-placed to create a designed, engineered 'deep-subsurface disposal facility'.

How would you describe the risks of living near a nuclear waste store?
Surface radioactive waste stores have radioactive waste that's solid, in steel containers and well packaged. The stores are controlled environments, and they're very closely monitored. I'm comfortable living near that kind of waste store, but I don't, just because of where I am in the country. But I don't think that's anything more than a temporary store. You can't assume that society will be able to maintain a temporary store. The waste needs to be moved to a geological disposal facility. Time is important for radioactive decay, and some of these materials have been judged to be dangerous enough that they need to go down into something that's not on the surface. It should be our responsibility to manage this and not pass it to future generations.

What's the least known thing about nuclear waste?
Radioactive waste doesn't glow in the dark. Also, all the radioactive waste that goes into this deep facility will be packaged in 300,000 waste packages, which are about wheelie-bin size.

© The University of Manchester / Getty / Illustration: Nicholas Forder

INSIDE THE SAMSUNG GALAXY Z FLIP

Is the flip phone becoming trendy once again?

WORDS **MARK SMITH**

It's pretty hard to imagine now, but there was a time when flip phones were cool. People loved the fact they were compact, easy to store in bags and pockets and that their screen was protected, too.

As smartphones became more popular and mass produced, flip phones were simply not feasible anymore. For a smartphone with internet access and apps that you'd want to use to stream videos and for gaming, a big, high-quality screen was a must.

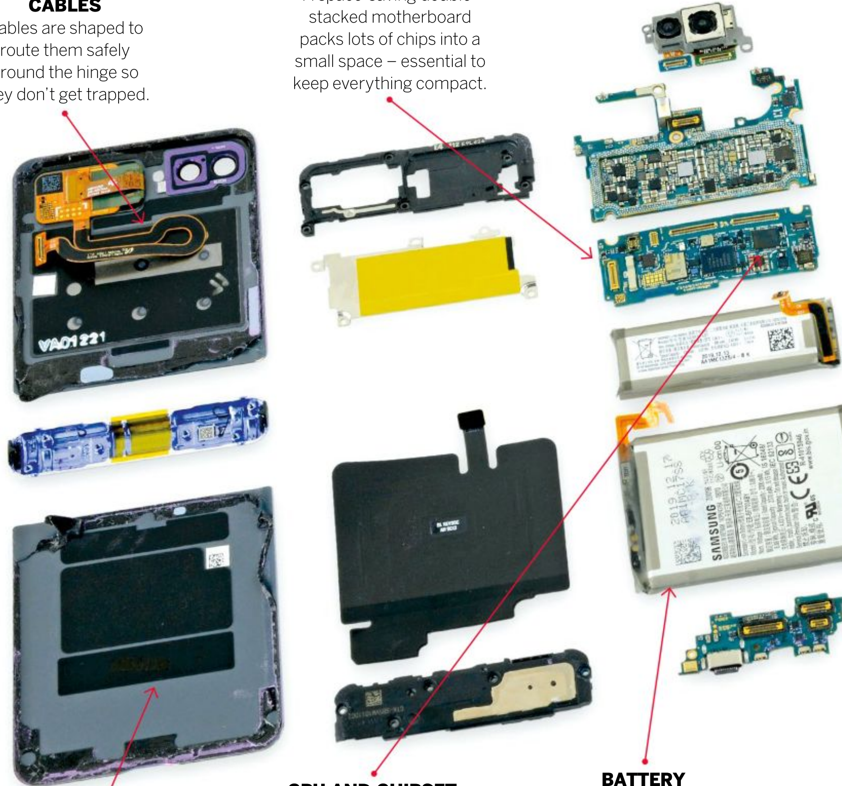
But that meant smartphone design became pretty formulaic. Manufacturers might have different bits of tech added here and there, but by and large, smartphones have always effectively just been glass rectangles. They all looked pretty much the same... until now. The Galaxy Z Flip is a smartphone and a flip phone, all in one.

Flexible glass means it can be closed over just like the flip phones of old, slipped into a bag or a pocket when not being used. When needed, it can be opened up to reveal a 6.7-inch dynamic AMOLED screen. Ultra thin and ultra tough, it can also be flipped into a right angle – ideal for putting on the table for making video calls and taking photos.

It's no slouch in the power department either, with a 3,300mAh battery that's designed to last all day on one full charge. A 5G version also comes with superfast 5G connectivity.

There's still some uncertainty about when people may actually be able to get their hands on the Galaxy Z Flip's successor, but who knows, maybe flip phones are becoming cool again?

Rebecca Hirst, Samsung's marketing director, unveils the Samsung Galaxy Z Flip folding smartphone in San Francisco, California



CONNECTING CABLES
Cables are shaped to route them safely around the hinge so they don't get trapped.

MOTHERBOARD
A space-saving double-stacked motherboard packs lots of chips into a small space – essential to keep everything compact.

METAL AND GLASS BUILD
An aluminium and glass construction provides a different look to the darker, denser steel frames on other modern phones.

CPU AND CHIPSET
The motherboard features 8GB of smartphone RAM layered on top of the Snapdragon 855 CPU.

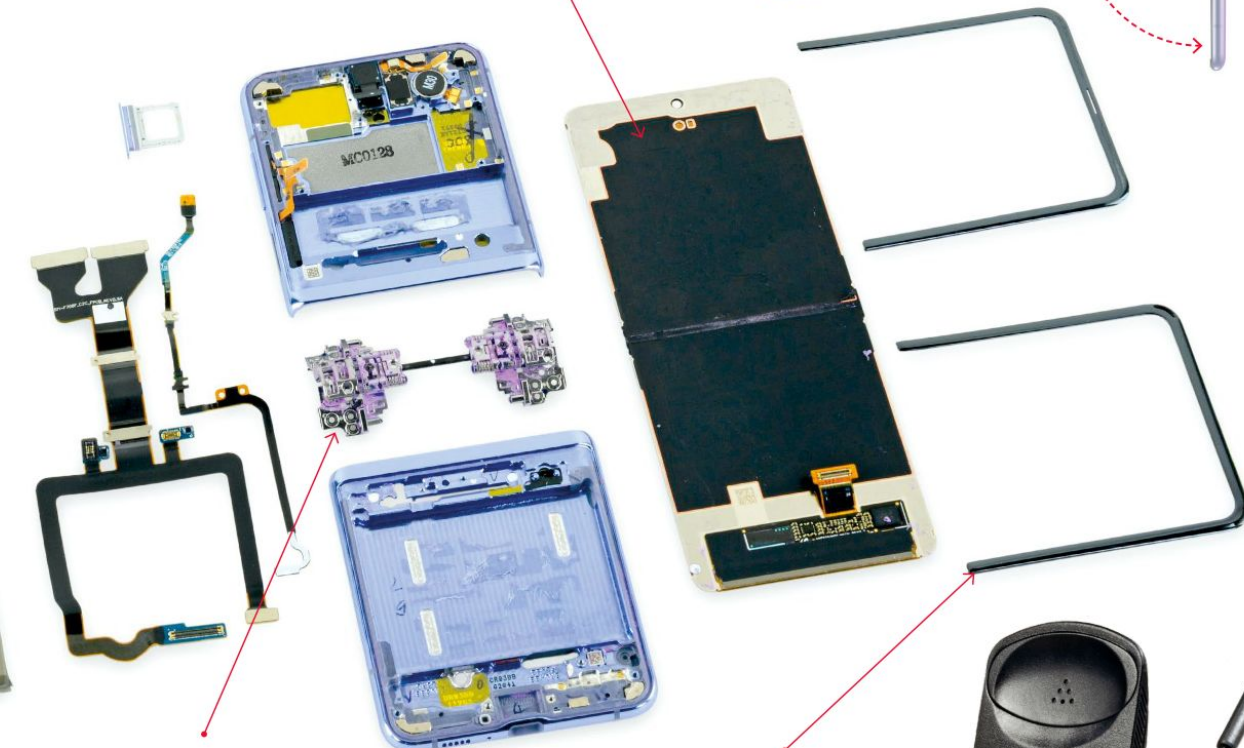
BATTERY
The phone features a 3,300mAh battery that is designed to last all day on a single charge.

"Flexible glass means it can be closed over just like the flip phones of old"

DID YOU KNOW? The technology that makes the new Galaxy Z Flip a possibility is Samsung's Ultra-Thin Glass (UTG)

THE INNER WORKINGS

We take a look inside to see what makes this new flip phone functional



SCREEN
The unique folding screen is made from Samsung's Ultra-Thin Glass (UTG) technology.

HINGE
The tech that makes a flip phone flip – the hinge.

BEZELS
Glued-down plastic bezels are designed to guard the phone's primary display.

AN OLD FAVOURITE

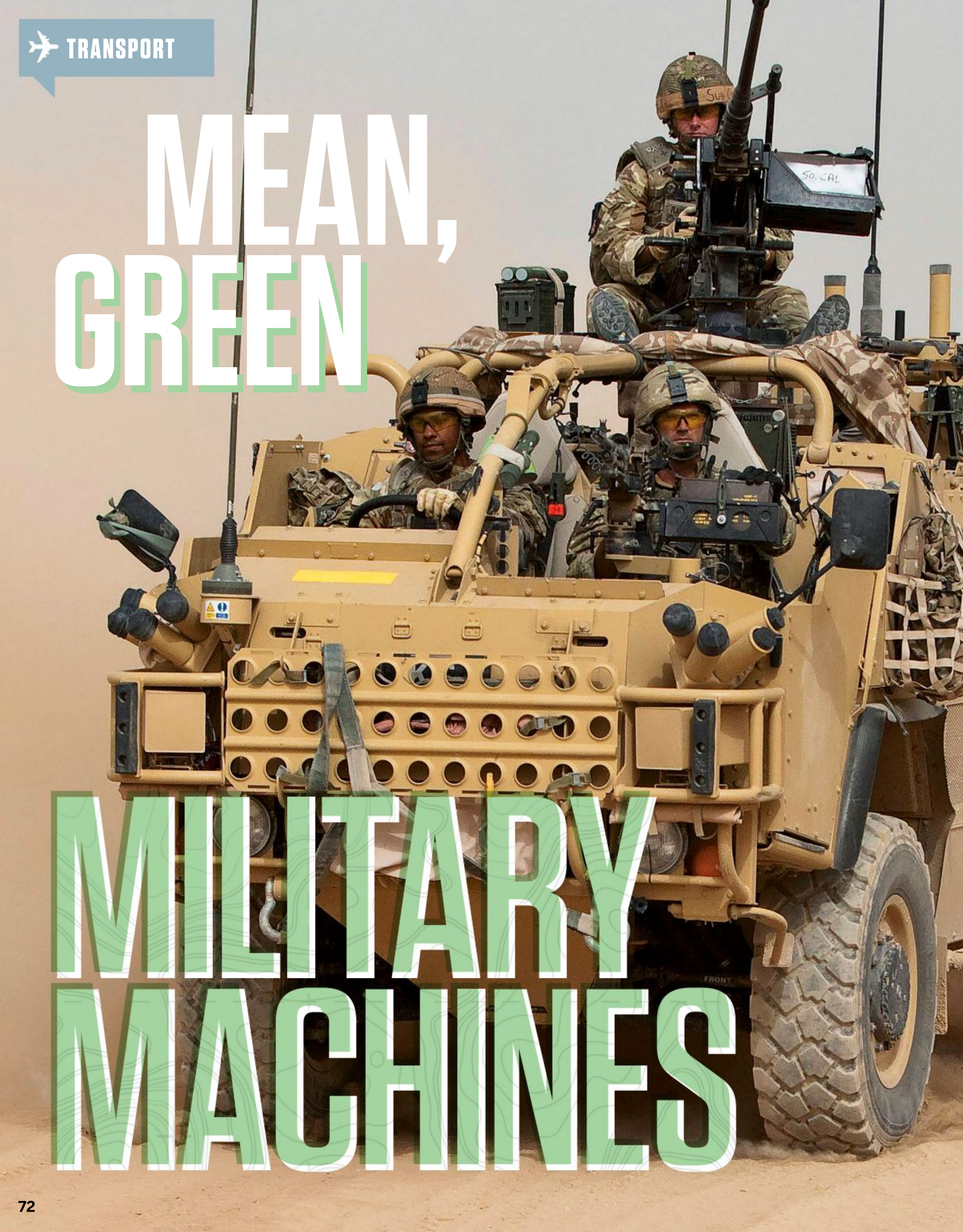
The Samsung Galaxy Z Flip may be a new phone with some pretty groundbreaking technology, but when it comes to design, it has its roots firmly in the past. Also known as a clamshell design, flip phones have been around since 1996. Motorola's StarTAC was small and portable, and weighed in at just under 113 grams, making it really popular with people who were still new to the idea of carrying mobile phones.

It featured calls, SMS text messages, vibrate alerts and a back-up battery. While not having any of the features we're all used to having on modern phones, it was practical, and became something of a fashion accessory, too.

An early Motorola flip phone

© iFixit / Getty / Samsung

MEAN, GREEN MILITARY MACHINES



DID YOU KNOW? Before hybrid, the army used generators to power field hospitals. In future they could use trucks to power them instead

The British Army is using hybrid power to turbocharge its toughest trucks

WORDS MIKE JENNINGS

Military motors are some of the biggest and loudest vehicles around, but that could change in the future, because the British Army is converting many of its vehicles from diesel to hybrid.

You might not expect a traditional organisation like the army to be at the forefront of hybrid technology, but it makes a surprising amount of sense. There are environmental concerns, of course: global warming is accelerating and something needs to be done.

Look from the environment to the battlefield and you'll find more reasons to move away from fossil fuels. Enemies won't hear an electric vehicle coming, for starters, and electric trucks are easier to drive, so soldiers have more awareness of their surroundings. They're quicker to accelerate, too, and they're often easier to control over tough terrain. The army has also found that vehicles with huge batteries are more useful for powering other bits of kit, from kettles to field hospitals.

But there are challenges too. The army's converted vehicles currently weigh more than their diesel predecessors, and their electronics are potentially susceptible to electromagnetic pulse attacks and fires. The army also needs to consider battery life span and disposal, and how much all of this will cost.

This is all an experiment – so it's no surprise that there are advantages and potential problems – but the army is still so enthusiastic about hybrid hardware that it's converted three vehicles. There's the MAN SV – a huge flatbed truck that lugs equipment in tough conditions. The Foxhound is an armoured van that's used by troops on patrol, and the Jackal is a lightweight all-terrain reconnaissance (recce) jeep.

They're beefy, varied rigs, and converting them is a major undertaking. The army has been smart here though. It's saved cash and increased reliability by using batteries, generators and other components that are already in production, and removed redundant parts like gearboxes and drivetrains to save weight.

HYBRID TOP TRUMPS

The MAN SV, the Jackal and the Foxhound are very different vehicles. Here's how they stack up

JACKAL	FOXHOUND	MAN SV
Batteries: **Two at 30kWh**	Batteries: **One at 60kWh**	Batteries: **Six at 30kWh**
Silent drive time: **30 minutes**	Silent drive time: **30 minutes**	Silent drive time: **80 minutes**
Top speed: **81 miles per hour**	Top speed: **70 miles per hour**	Top speed: **55 miles per hour**
Weight: **6,650 kilograms**	Weight: **7,500 kilograms**	Weight: **6,000 kilograms**
The Jackal is a recce vehicle, so it's compact, relatively light, very fast and manoeuvrable.	**The Foxhound has loads of armour, so it's heavy, but it's still not much slower than the Jackal.**	**The SV is designed for transporting equipment. It's not fast, but it has a long range.**

Troops can live out of the Jackal if necessary, so having onboard batteries is useful

AR ZONE

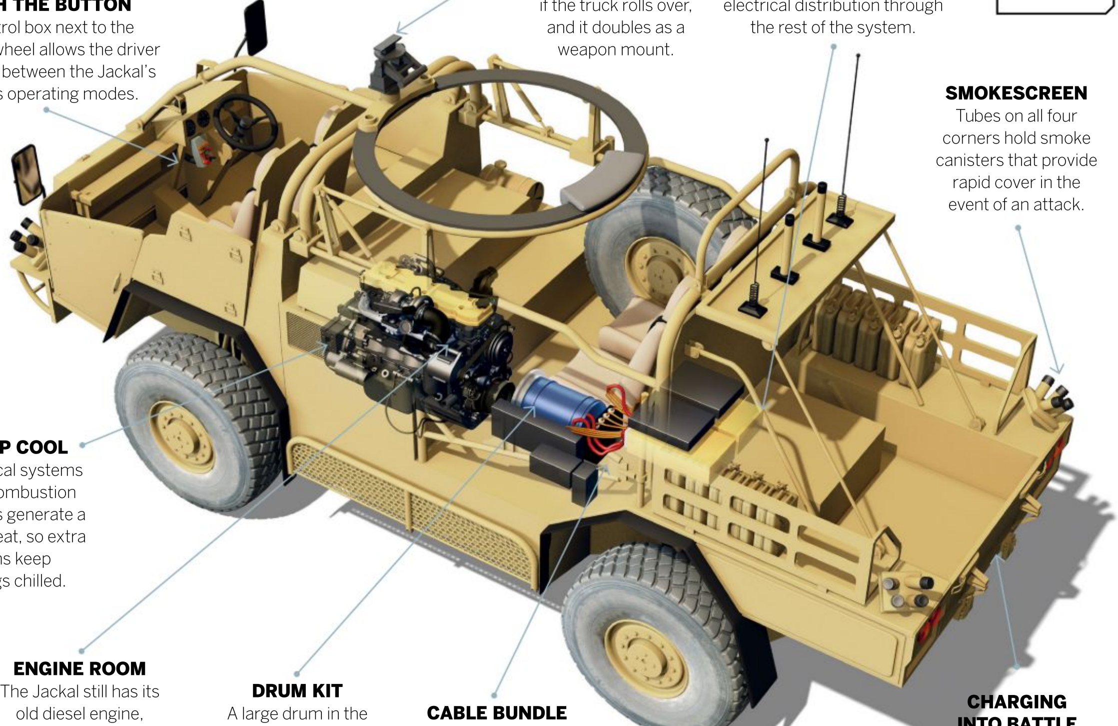
The MAN SV can charge from an external source, just like conventional electric cars

AR zone

SCAN HERE

INSIDE THE JACKAL

Loads of hybrid hardware is crammed into the Jackal. Here are the key elements of this nimble vehicle



ROLLING OUT
The Jackal's roll cage protects the occupants if the truck rolls over, and it doubles as a weapon mount.

REMOTE CONTROL
A sturdy box sits above the batteries and controls electrical distribution through the rest of the system.

PUSH THE BUTTON
A control box next to the steering wheel allows the driver to switch between the Jackal's various operating modes.

SMOKESCREEN
Tubes on all four corners hold smoke canisters that provide rapid cover in the event of an attack.

KEEP COOL
Electrical systems and combustion engines generate a lot of heat, so extra fans keep things chilled.

ENGINE ROOM
The Jackal still has its old diesel engine, which works in conjunction with the new electric components.

DRUM KIT
A large drum in the base of the Jackal houses the generator, which powers the electric motor.

CABLE BUNDLE
Thick, heavy-duty cables carry electricity from the batteries to the rest of the vehicle.

CHARGING INTO BATTLE
The battery packs are hidden away inside the Jackal – they're at the rear and well-protected.

BATTERY MEETS ENGINE

Hybrid vehicles combine battery power with conventional engines. The mix of these technologies means that hybrid vehicles can be powered in three ways: by the battery, by the engine or by those two components working together. Most hybrid vehicles have a conventional engine and fuel tank alongside batteries, a generator and an electric motor. If you're using pure battery power, the engine uses petrol or diesel to run in the background, charging the batteries and increasing the car's range. And if you want to combine battery and engine power, vehicles can switch between the power sources and recover energy when you brake.

There are various kinds of hybrid vehicles, too. Parallel hybrids are the most common and use any of the three propulsion methods. Range-extender hybrids only use their engines to produce energy for the electric motor, and plug-in hybrids are either charged by the engine or by an external source, like a plug.

Hybrids combine conventional engines with electric technology for more efficient performance

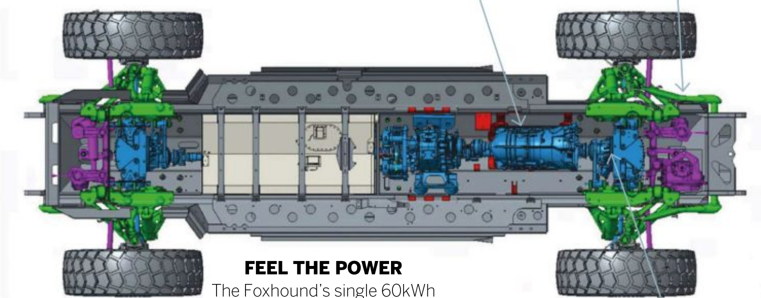
DID YOU KNOW? The MAN SV stores 180kWh of energy – that's enough to charge 17,000 smartphones or power a house for 18 days

HYBRID HOUND

Plenty of components were removed to convert the Foxhound to hybrid technology. Here's what's changed

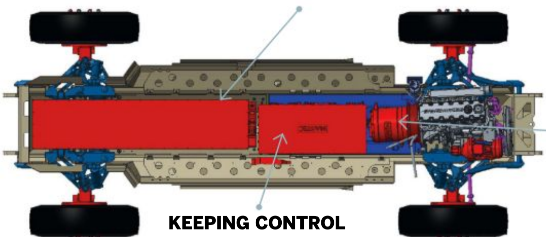
SHIFTING GEAR
The Foxhound's gearbox, differentials and drive shafts were all extracted before the hybrid conversion.

BUMPY RIDE
The suspension is kept in the Foxhound – important for a truck that needs to tackle rough terrain.



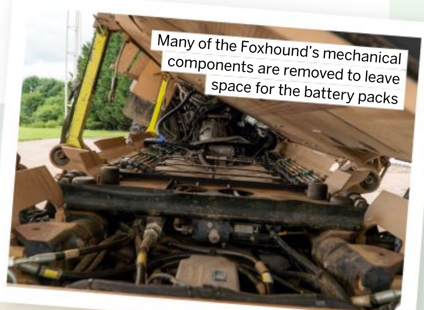
FEEL THE POWER
The Foxhound's single 60kWh battery stretches along much of the underside of the vehicle.

POWER PLANT
The Foxhound's diesel engine is still in place, even if it won't be powering the vehicle at all times.



BRIDGE THE GAP
The Foxhound's generator sits next to the engine, where it can be used to charge the battery.

KEEPING CONTROL
A control box sits in the middle of the Foxhound and ensures that the electrical and diesel systems coexist happily.



Many of the Foxhound's mechanical components are removed to leave space for the battery packs

The versatile Foxhound is used by armies around the world as a troop patrol vehicle

THE HYBRID HEAD HONCHO

Lieutenant Colonel Sutthery is a driving force behind the army's hybrid trucks

Does hybrid technology mean you can use these vehicles in different ways?
There's a whole host of different uses for vehicles like the Jackal, Foxhound and MAN SV. The army has already deployed them in varied roles in the past, including humanitarian support in the Caribbean and in Sudan, as well as in peacekeeping missions in Bosnia and Kosovo. That's important, but electrification will give us more choice. We'll be better able to support other government departments and organisations in areas where they don't have power – imagine the impact of arriving in a disaster zone and being able to supply power to support people.

Will moving to hybrid systems mean the army's vehicles are more expensive?
At the moment we're using commercial technology to help keep costs down and keep things easier because we need to embrace these new technologies quickly and on-budget. While it does cost more to convert these vehicles, those conversions increase reliability, reduce the number of spares that we need, reduce the time spent in workshops and reduce fuel consumption, so that leads to long-term savings.

What do you think you'll be using in the future, after hybrid?
Right now we need to work on delivering enough power to support our mobile forces, and all militaries are facing the same conundrum right now. Alternative battery technologies and power generation methods will hopefully improve the amount of time we can go between charges, but lots of this technology is still immature. We'll continue to monitor and assess the emerging technology in this area – it's rapidly evolving. As for the future, full electric power is the dream.

© Ministry of Defence / Mike Jennings / Getty / General Dynamics / Jakal Illustration: Adrian Mann / Mike Jennings

This oil painting by Horace Vernet depicts Napoleon and his military personnel on horseback after a battle

WHO WAS NAPOLEON BONAPARTE?

How the first emperor of France came to power – and his dramatic downfall

WORDS **OWEN JARUS AND SCOTT DUTFIELD**

Born on the island of Corsica in 1769, Napoleon Bonaparte was christened Napoleone di Buonaparte, but later changed his name when he married in 1796. He rose from a family of minor nobles on the French island of Corsica to become ruler of much of continental Europe.

Napoleon attended military school in Brienne, France, from 1779 to 1784. After completing courses in Brienne, he attended École Militaire, a more advanced military academy in Paris. He graduated in 1785 and was commissioned as an artillery officer in the French army. The French Revolution, which started in 1789 and led to the beheading of King Louis XVI, created an unstable political environment in which he could use his military prowess to rapidly rise to power.

His ascent began in 1793 when a group loyal to the French monarchy captured the city of Toulon with help from the British. The republican government ordered a military expedition to retake the city, and Napoleon served as one of the operation's senior leaders, developing a battle plan that led to the city's recapture. Then, in 1795, he helped lead a military force that put down a rebellion in Paris.

In 1796 Napoleon was appointed commander of French forces in Italy. Within a year his troops had conquered much of Italy and part of Austria. The military success in Italy boosted his reputation in France, which led him to a greater position of power in France's republican government. In 1798 he led a French military expedition to Egypt, a country controlled by the Ottoman Empire. His expedition succeeded in taking northern Egypt, though Napoleon's forces were cut off when the British defeated a French fleet at the Battle of the Nile.

While Napoleon's troops were stranded in Egypt, the situation was deteriorating for the French republic. Austria and Russia went to war with France, joining Britain and the Ottoman Empire, and revolts broke out in France as those still loyal to the monarchy tried to overthrow the government. Taking advantage of the situation, Napoleon left Egypt for France in 1799, leading a military coup that saw him appointed 'first consul' of France.

By 1802 he had a remarkable military record: he had put down rebellions in France, reconquered Italy and forced the other countries to sue for peace by defeating their armies on the battlefield. His influence as first consul steadily increased, and in 1804, after a referendum, he was voted in as emperor of France. To keep hold of his newfound power, the nascent emperor made heavy use of censorship to prevent the expression of any opposition.

Over the course of his 15-year rule, Napoleon fought in 60 battles, losing only seven. His final fight came in 1815, when he was defeated at the Battle of Waterloo in what is now Belgium and exiled to Saint Helena, an island in the South Atlantic, far from France. Napoleon lived the last six years of his life on this remote island, dying of gastric cancer in 1821, aged 51.

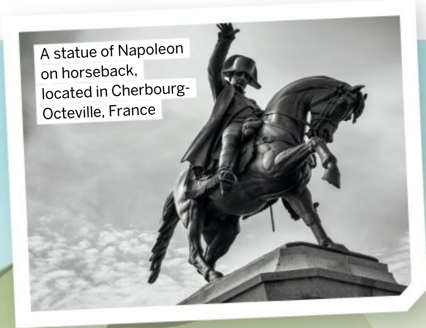
HOW NAPOLEON LOST HIS GRASP ON EUROPE

Napoleon's worst defeat came when he tried to invade Russia in 1812. With more than 400,000 soldiers at his command, Napoleon succeeded in taking Moscow, but the victory was short-lived. Much of the city was destroyed, and with supplies running short, Napoleon was forced to retreat, losing many men to the harsh winter, malnourishment, disease and Russian attacks.

By 1813 Napoleon remained on the defensive, with troops from Russia, Great Britain, Spain, Austria and Prussia gradually pushing his army back towards France. In 1814 forces from those countries invaded France, reaching Paris in April. They forced Napoleon to abdicate, sending him into exile on the island of Elba in the Mediterranean. Napoleon came back to France in 1815 and regained power, but he ruled for only 100 days or so before he was defeated at the Battle of Waterloo.

The British Army in action at the Battle of Waterloo by the artist Thomas Sutherland

DID YOU KNOW? Napoleon wasn't that short. At 1.65 metres, he was 2.5 centimetres smaller than the average male of his time


A statue of Napoleon on horseback, located in Cherbourg-Octeville, France

NAPOLEON'S GREATEST VICTORY

How Napoleon achieved his biggest military triumph at the Battle of Austerlitz

1 NAPOLEON'S TRAP
Having feigned weakness at his army's right flank, Napoleon concentrated his forces on drawing the coalition of Russian and Austrian soldiers to a trap in the Pratzen Heights.

2 FIGHT AT THE HEIGHTS
Once assembled at the Pratzen Heights, France's inferior numbers benefited from fighting between the walls of the village buildings that made up the landscape of the Heights.

3 CAVALRY CLASH
The left flank of Napoleon's army fought on horseback in an attempt to cut off Russian soldiers from the main battle.

4 THE IMPERIAL GUARD
The Russian Imperial Guard made initial gains against Napoleon's troops. Heavy artillery halted the Russians at first, until they responded with a bombardment of their own.

5 FRENCH ADVANCEMENT
The Imperial Guard's success was short-lived, as the arrival of another French military unit swarmed the soldiers and delivered a devastating counterattack.

6 RUSSIAN RETREAT
Due to France's advantage at the Pratzen Heights and the retaliation from the centre of the battlefield, Russian forces began to lose their grip on the battle and started to retreat.

7 ICY GETAWAY
In full retreat, what was left of the Russian and Austrian forces attempted to flee across a series of frozen ponds. Many drowned in the freezing waters, and the rest were captured and imprisoned.

© Getty / Alamy

DUST BOWL DISASTER

Why were the southern US plains host to such huge and intense dust storms in the 1930s?

WORDS **CALLUM MCKELVIE**

During the 1930s, the Great Plains of the US – an expanse of grassy flatland which lies between the Mississippi River and the Rocky Mountains – were transformed. Economic downturn, agricultural factors, federal policies and extreme weather turned the area into a drought-ridden desert. The resulting dust storms would spread over 27 states, and by 1939 over 75 per cent of topsoil would be lost to erosion.

Originally the plains were home to semi-arid grasslands, but the Homestead Act of 1862, along with subsequent similar laws, handed settlers 160 acres of land. The grasses were ploughed, and dry non-native wheat was planted. Over successive decades, severe environmental damage began to occur. During the 1920s, the desire from farmers to battle the Great Depression by increasing their crop load led to further devastation, as marginal lands were ploughed and soil conservation practices abandoned.

In 1931 the first major drought occurred, turning the land to dust. The strong winds in the area created devastating dust clouds that would cover entire homes and farms. Numerous livelihoods were destroyed due to the Dust Bowl, and families were forced to migrate west, becoming labourers. In 1935, following a series of terrifying storms, reporter Robert E. Geiger visited the region and described in detail what he saw. It was Geiger who, upon seeing the damage done to the region, coined the term Dust Bowl. From that point on, Geiger's phrase would be used to describe the worst affected area during arguably America's worst drought.

Following these events, and faced with an increasing number of rural farming families struggling in poverty and in need of assistance, the US government enacted a series of laws to attempt to halt both the drought and the poverty it was causing. By 1939 the first rains began to fall, but the memory of the Dust Bowl and the chaos it caused remains.

Above: Numerous livelihoods were destroyed as fertile farmland was turned to dust

Above inset: Some of the storms were so severe that they could bury entire houses

"The resulting dust storms would spread over 27 states, and by 1939 over 75 per cent of topsoil would be lost to erosion"

DUST AND DOOM

1929

An economic crash caused the Great Depression, creating mass unemployment. When the Dust Bowl occured, many farmers were made jobless.

1931

Droughts began to hit the Midwest and Southern Plains. The strong winds resulted in the first of the dust storms, which slowly increased in intensity.

1933

38 dust storms were recorded this year, building on the previous year's 14.

1933

Roosevelt became president and sought to end the drought through promoting soil conservation, resettling farmers and aiding migrant farmers.

1934

Dust storms reached their peak, covering 75 per cent of the country and stretching across 27 states.

BLACK SUNDAY

On 14 April 1935, the Dust Bowl's worst dust storm occurred. Beginning in Oklahoma at around 16:00, temperatures dropped by over 15 degrees Celsius and a billowing wall of pitch-black dust, accompanied by 40 mile per hour winds, swept across the land. The dust was carried thousands of metres into the air and blotted out the Sun, the intensity of the storm causing many to believe the world was coming to an end.

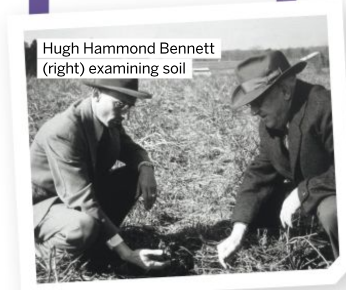
By 19 April the storm reached Washington DC. Bakers had to keep freshly baked bread away from windows so that it would not get dirty, and any washing hung outside was found covered in dust. However, the storm was perfectly timed for Hugh Hammond Bennett, the 'father of soil conservation', who at the time that Black Sunday hit Washington was giving a lecture to Congress, imploring them to take action against the ongoing drought. Having now experienced a devastating storm firsthand, Congress would push the Soil Conservation Act through a mere year later.


Black Sunday, the worst of the dust storms, carried 300,000 tonnes of dust across the US

SAVING THE SOIL

Hugh Hammond Bennett's role in the reversing of the damage done to the Great Plains cannot be understated. In 1903 he began his career as a soil surveyor, and over successive years became convinced of the dangers of soil erosion, writing numerous papers such as 1928s *Soil Erosion: A National Menace*. In 1933 he helped establish and became director of the Soil Erosion Service.

Bennett was known for his dramatic speeches and empowering delivery, his 1935 speech to Congress being integral to helping end the continuing damage being done to the soil. It was said that Bennett "combined science with showmanship" and was able to convince the powers that be of the importance of soil conservation.


Hugh Hammond Bennett (right) examining soil

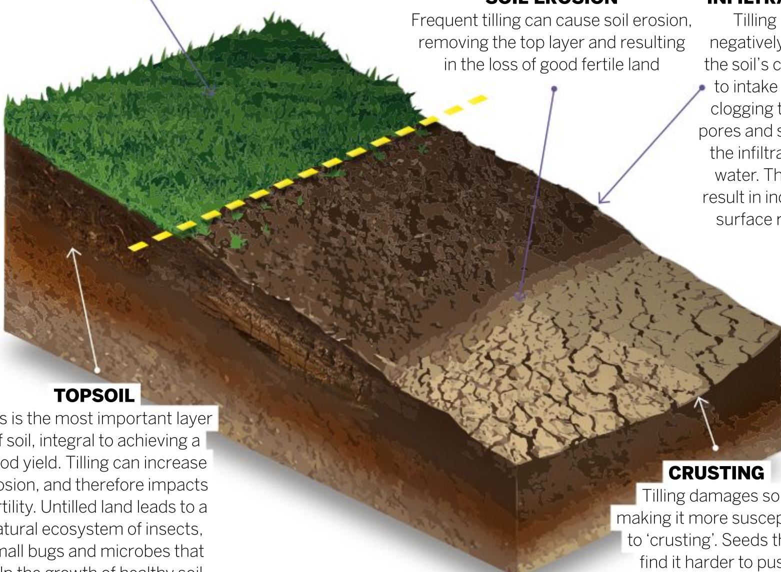
TO TILL OR NOT TO TILL?

Over-tilling contributed to the Dust Bowl, but just how did this process affect the soil?

INCREASED WATER INTAKE
Untilled soil can store more water. As plant roots break through, water and air can travel deeper and make a way for the next set of roots to grow.

SOIL EROSION
Frequent tilling can cause soil erosion, removing the top layer and resulting in the loss of good fertile land

WATER INFILTRATION
Tilling can negatively affect the soil's capacity to intake water, clogging the soil pores and stopping the infiltration of water. This can result in increased surface runoff.



TOPSOIL
This is the most important layer of soil, integral to achieving a good yield. Tilling can increase erosion, and therefore impacts fertility. Untilled land leads to a natural ecosystem of insects, small bugs and microbes that help the growth of healthy soil.

CRUSTING
Tilling damages soil, making it more susceptible to 'crusting'. Seeds then find it harder to push through the top layer.

1934
Roosevelt launched the Shelterbelt Project, planting rows of trees on the Great Plains in order to protect the land against the winds.

14 April 1935
The most severe dust storm occured, carrying over 350 million tonnes of dust all the way to the Eastern Seaboard.

27 April 1935
Congress passed Public Law 74-46, also known as the Soil Conservation Act, which allowed for the creation of the Soil Conservation Service under the direction of Hugh Hammond Bennett.

1937
The Farm Security Administration was created. This provides farmers with small loans to buy the land they work and possibly expand, reducing poverty.

1939-1941
In autumn 1939, near-normal rainfalls began. This, along with the onset of WWII, helped improve the economic situation, as there was now a greater demand for goods and farm produce.

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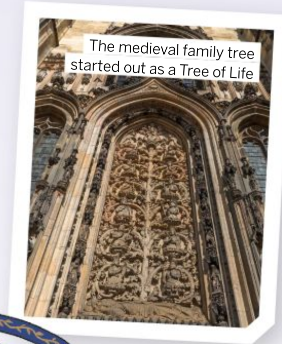
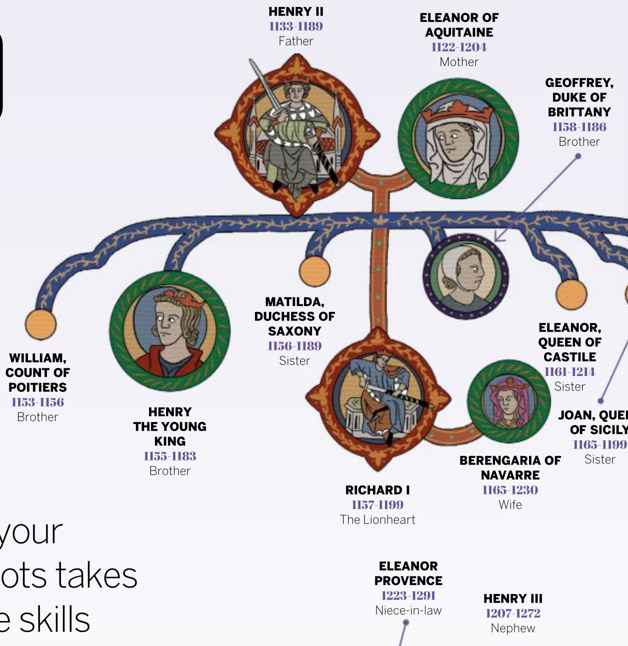
HOW TO READ FAMILY TREES

Just like any great detective, tracing your family's historic roots takes clever investigative skills

WORDS **JO ELPHICK**


The medieval family tree started out as a Tree of Life



ROYAL RELATIONS

English king Richard the Lionheart was a legend in his lifetime. Any family connection was highly favourable, as shown in this famous family tree

Everyone knows what a family tree looks like, with its branches growing out and upwards, further back in time. Although there are different forms of family tree, the most familiar arrangement displays a map of your roots and how your ancestors are related to one another.

Family trees are read from bottom to top, with each group of people on the same horizontal line representing a separate generation. Your parents' names will be above you, your siblings will be written either side of you and any children you have will be below you. If your children have a baby, your grandchild will be added beneath them. Your mother's parents will be above her and your father's parents will be above him, showing all four of your grandparents. Any siblings that your parents may have – your aunties and uncles – will be written alongside them, just as your siblings are displayed beside you. Gradually, the branches spread further out and the roots further downwards as each new generation is born.

The most famous family tree is that of the British royal family, and it's fascinating to see how they are related to other royal families around the world. As each family tree becomes bigger and more complicated, many branches merge with other trees, and that is why nearly all Europeans can trace their family ancestors back to royal lineage via Charlemagne or William the Conqueror.


A typical family tree uses the drop line chart method, which is far easier to read than a circular or wheel chart


Celebrated actor Tom Hanks is one of many who claim to be related to Queen Elizabeth II

FAMOUS FAMILY TREE LINKS

Genealogists have discovered that many celebrities share a family tree with some very important historical figures. Meghan Markle and Winston Churchill are sixth cousins five times removed, while actress Helena Bonham Carter is related, by marriage, to James Bond author Ian Fleming.

Woody the cowboy doll may well be king of the toys, but his voice actor Tom Hanks also has a royal connection: he and Queen Elizabeth II are 24th cousins. He also happens to be a descendant of Abraham Lincoln. Other famous connections include Benedict Cumberbatch, who plays Sherlock Holmes, and the author Sir Arthur Conan Doyle, who created the celebrated detective.

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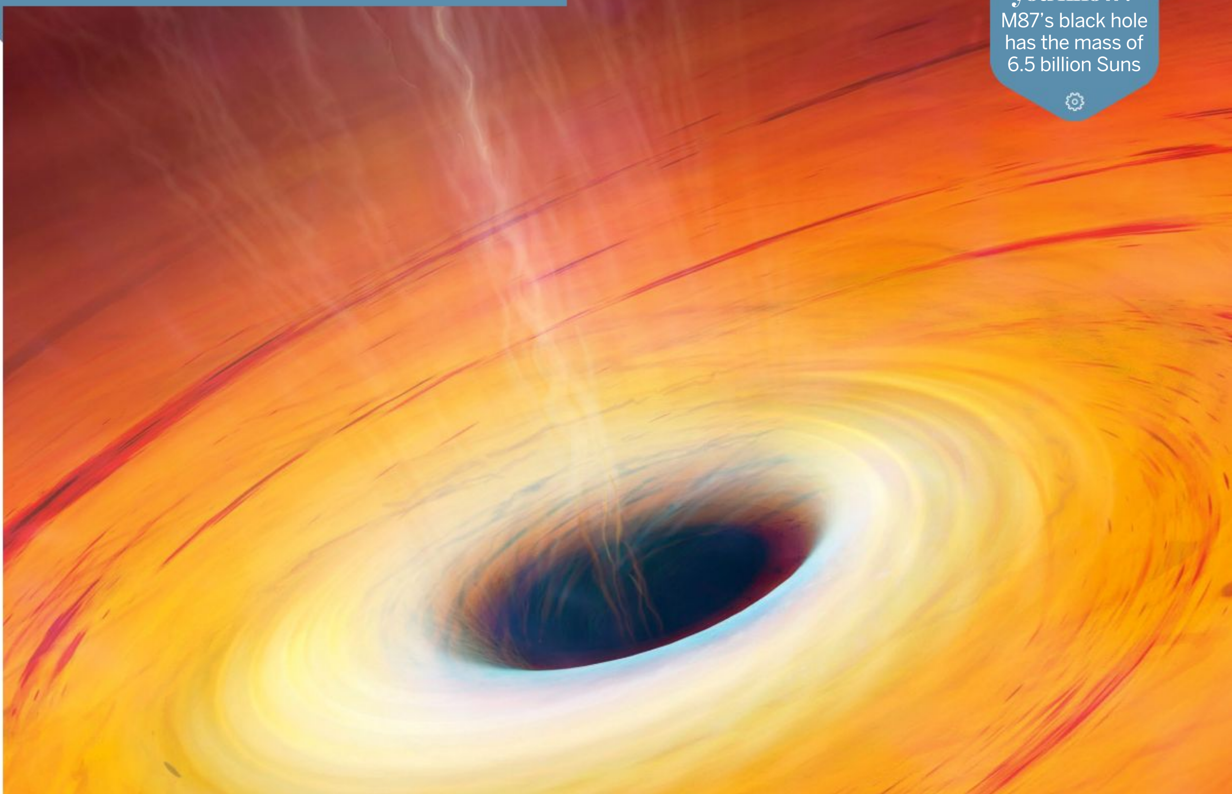


Did you know?
M87's black hole has the mass of 6.5 billion Suns

MEET THE EXPERTS

Who's answering your questions this month?

Jo Elphick
History and forensic science

Andy Extance
Chemistry, tech and science

Andrew May
Space, transport and science

Lauren Eyles
Animals, the environment and science

Does every galaxy have a massive black hole in the centre?

Rebekah Jimenez

To date, only one supermassive black hole has been observed directly, deep in the core of the galaxy Messier 87. But astronomers believe that most galaxies, with the exception of very small ones, have similar black holes lurking at their centres. The evidence for this is indirect, but compelling. For example, stars and gas whiz around galaxies at such high speeds it's clear they are in orbit around a very small, extremely massive object. **AM**

The famous first image of the supermassive black hole at the centre of M87

Cavemen often drew the animals around them, like these horses

When did cavemen first paint in caves?

Helen Leader

The oldest known cave painting was discovered in Indonesia, on the island of Sulawesi, and is thought to be at least 45,500 years old. In order to recreate pictures, scientists claim that humans needed a 'higher order consciousness' – in other words, a sophisticated way of thinking. Until the Indonesian paintings were discovered, the earliest known cave artwork was in France, which was thought to have been painted around 32,000 years ago. JE

WHY ARE 'CAT YEARS' SO MANY HUMAN YEARS?

Matt Hansel

Humans live much longer than cats, so the idea of cat years was decided to help determine what stage of life a cat is in. But cats actually age differently to humans. The first year of a cat's life equates to about 15 human years, and the second about nine. **LE**

WHAT'S THE DEADLIEST SUBSTANCE TO HUMANS?

Yasmine Hubbard

Using a measure of toxicity called the median lethal dose (LD50), the deadliest substance is botulinum toxin, with an LD50 of a billionth of a gram per kilogram of body mass. Symptoms develop within one to three days. **AM**

Perkins' original stoppered bottle of Mauveine

Who invented food colouring and why?

Catherine Smith

Natural food colourings, such as spinach, saffron and beetroot, have been used for thousands of years. But a synthetic organic dye called mauveine, also known as aniline purple, was accidentally created by British chemist William Henry Perkin in 1856 when he was trying to synthesise a medicine for malaria. The synthesis yielded a 'failed' black solution, but when he cleaned the flask with alcohol, he noticed a vivid, purple compound. The dye was being used in clothes and drugs as a cheaper alternative to natural dye by the early 20th century, and as a food colouring as well, until the chemical was linked to certain types of cancer. **AE**

© Getty

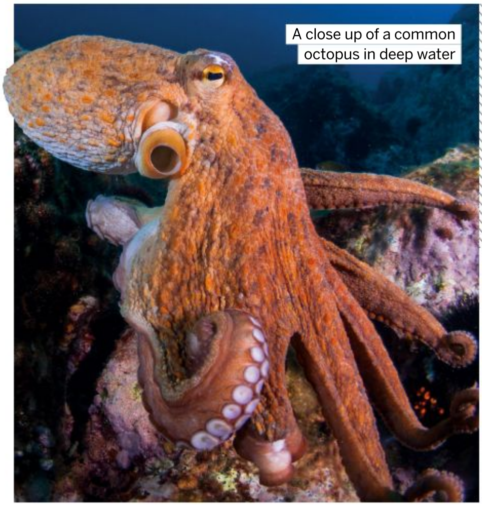

Through the canopy of Scots pine evergreen trees

Did you know?
Evergreen trees are perfect wildlife homes

WHY DON'T EVERGREEN TREES HAVE LEAVES?

Riki Iwasaki

Evergreen trees do have leaves, they're just different. Rather than shedding their leaves at the end of the growing season like deciduous trees and hibernating for winter, evergreens keep their leaves all year round. Deciduous trees like oak are big, flowering plants. They have an annual cycle where they grow lush, green leaves; the leaves change into stunning red, orange and yellow colours; they lose their leaves and it all starts again. Evergreen leaves can be thicker and more of a needle shape, often with a waxy coat to reduce moisture loss. **LE**


A close up of a common octopus in deep water

Do all animals have red blood?

Maciej Kowalczyk

Most animals do have red blood, but not all of them. The animal kingdom can be rather surprising, with blood ranging from red, blue, green and purple. Snails, spiders, crustaceans, squid and octopuses all have blue blood in common. However, some land and marine worms, as well as leeches, have green and purple blood. The difference in colour is because animals are made up of different proteins, which might be better suited to the environments they live in. **LE**

DOES THE FORCE OF GRAVITY STILL EXIST AT ZERO KELVIN?

Arthur Chayun

There's no definitive answer to this question, because the laws of physics prevent any system from reaching absolute zero temperature, approximately -273.15 degrees Celsius. But there's no reason to expect gravity to vanish at that point. On the contrary, its existence is one of the things that makes it impossible to achieve absolute zero. In practice, the force of gravity remains unchanged at the lowest temperatures attained so far, such as those in the International Space Station's Cold Atom Laboratory, which are just a few trillionths of a degree above absolute zero. **AM**


Astronaut Christina Koch making adjustments to the Cold Atom Laboratory on board the ISS

DO POLICE PUT CHALK AROUND BODIES AT CRIME SCENES, OR IS THAT JUST IN FILMS?

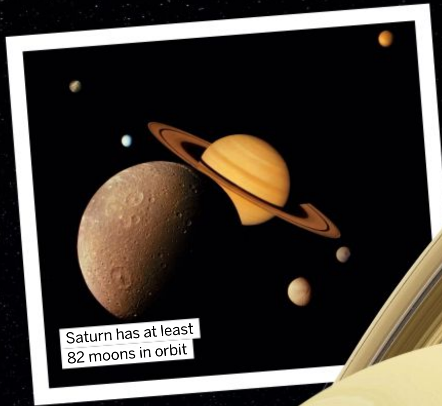
Alice Bader

Although chalk outlines were sometimes used to show press photographers where a body was found, the police no longer do this for fear of contaminating the crime scene. **JE**

WHY ARE THERE DIFFERENT SHAPES OF CHIMNEY POT?

Glen Green

Chimney pots are designed to extend the smokestack to produce a better draft for the fire. Chimneys with more than one pot signify multiple fireplaces on different floors. Since they're visible from outside, homeowners chose different styles to show off their fashion sense and wealth. **JE**



Saturn has at least 82 moons in orbit

Do the outer planets have many more moons than the inner planets because they're so big?

Jonathan Pritchard

Yes, that's right. Their stronger gravity allows them to capture objects that would otherwise have been asteroids or small planets in their own right. Astronomers are still discovering tiny moons in the outer Solar System, but Saturn is the current record holder with 82. **AM**

© Getty

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IF A HUMAN DOESN'T EAT ANY FOOD, HOW LONG CAN THEY LIVE? WHAT ABOUT IF THEY DON'T DRINK WATER?

Shane Burns

It's difficult to know exactly, but one thing we do know is that humans can survive longer without food than without water. The body would start to find alternative food sources in fat reserves, but water is vital for the body to function and stay alive. **LE**

WHY DO ONIONS MAKE YOU CRY?

Blaine Marshall

Onions produce a chemical known as syn-Propanethial-S-oxide, which is released when an onion is cut and triggers glands in our eyes to release tears. **LE**

Seagull droppings make a terrible mess of car windows

Why is bird poop whitish?

Emma Anderson

The white stuff that you find splattered all over your windows isn't bird poop. It's actually bird urine. The poop is the small, black blob that you often find in the middle. While mammals poop and pee from separate places, birds eject all their waste products from one exit point: the cloaca. The bird changes the liquid urea into uric acid, which forms a thick, white paste. The black poop is excreted at the same time, and therefore shows up in the centre. However, not all birds behave in this way. The ostrich expels urine from its mouth before defecating from its cloaca… gross! **JE**

Sea hare with its eggs among the seaweed

Did you know?
Most land and sea slugs are both male and female

Are sea slugs related to land slugs?

Soren Guibord

Both land and sea slugs are molluscs in the class Gastropoda, which means 'stomach foot', so are closely related and found all over the world. On land, slugs have no shell, but it's not that straightforward in the sea. Some species called nudibranchs start off with a shell, but lose them as an adult and have external gills. There are even some that look like slugs, but aren't slugs at all. Sea hares have an internal shell, so are actually a sea snail, and sea cucumbers are in a totally different family altogether. **LE**

Do sea plants photosynthesise?

Jamie Aunger

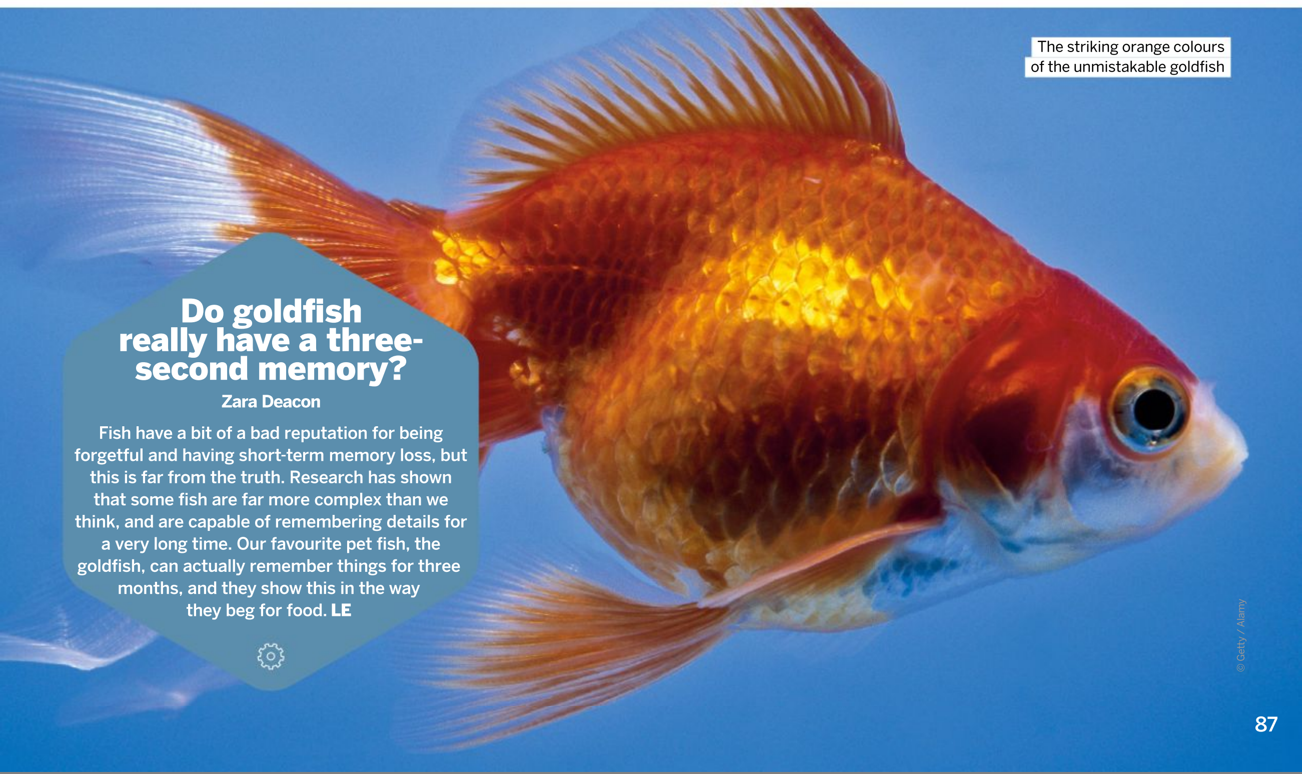
Yes, they do. Plants in the sea, like seagrass, use light from the Sun that passes through the water to produce their own food through photosynthesis. During this process, seagrass absorbs and stores carbon dioxide from the ocean much faster than tropical rainforests, helping the fight against climate change. **LE**

If you unfolded a contrabassoon, it would be over five metres long

What are the highest and lowest instruments?

Sebastian Ordoñez

At around 32 centimetres long, Piccolos are half the size of a standard flute, giving them the highest pitch of all orchestral instruments. The lowest sound comes from the contrabassoon, or double bassoon, a reed instrument that can play a whole octave (an eight-note interval) lower than the standard bassoon. It's also twice as long as the standard bassoon, has a larger reed – the bit that vibrates to produce the sound – and curves around itself twice, like a snake. **AE**



The striking orange colours of the unmistakable goldfish

Do goldfish really have a three-second memory?

Zara Deacon

Fish have a bit of a bad reputation for being forgetful and having short-term memory loss, but this is far from the truth. Research has shown that some fish are far more complex than we think, and are capable of remembering details for a very long time. Our favourite pet fish, the goldfish, can actually remember things for three months, and they show this in the way they beg for food. **LE**

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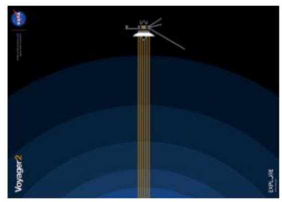

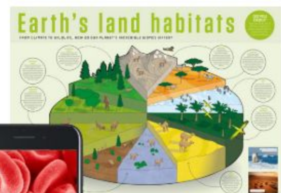

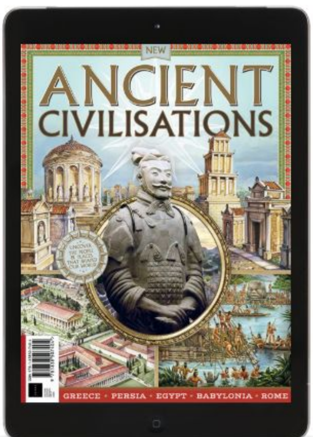

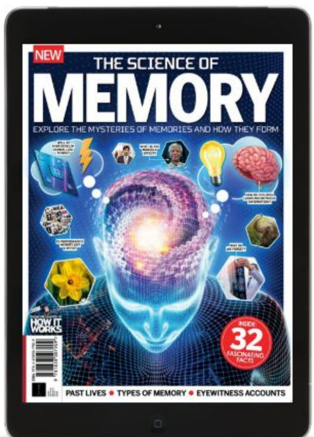

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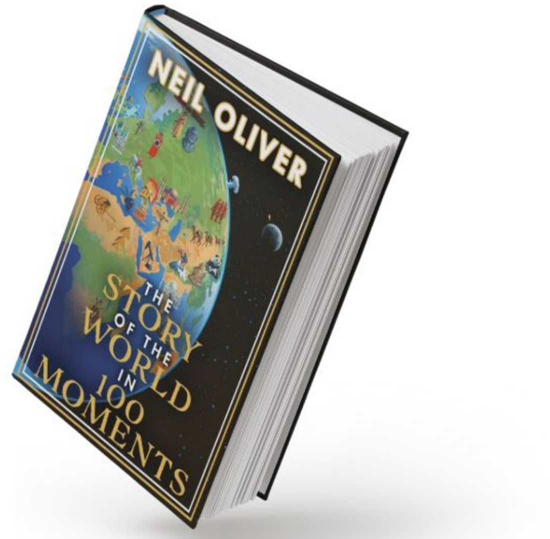


THE STORY OF THE WORLD IN 100 MOMENTS

IT'S HIS STORY, NOT THE STORY

AUTHOR **NEIL OLIVER**
PUBLISHER **BANTAM PRESS**
PRICE **£25 (APPROX. $34.65)**
RELEASE **16 SEPTEMBER**

You may have noticed, if you're a **How Works** subscriber or a regular reader, that we enjoy putting a list feature in pretty much every issue we make. And the more items in that list that we don't know about or don't expect to see, the better.

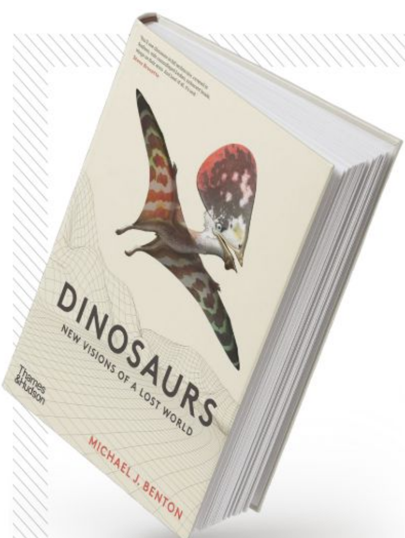
Historian and TV presenter Neil Oliver's *The Story of the World in 100 Moments* is mostly made up of key points in history that we either had no knowledge of, or the very briefest acquaintance with. That's good: it's refreshing not having to read about the same stuff in history – turning points in World War II, Charles Darwin's theory of evolution, the discovery of the New World in the 15th century – the kind of content we'd think of including if we had put this book together. Instead we get expert insight into moments of world history that slipped under our radar, what Oliver refers to as: "My story of the world... my 100 moments."

It includes one of the earliest concepts of money, formed by the ancient people of the Yap archipelago in the western Pacific, who traded giant doughnut-shaped stones called rai with each other as dowries or in return for goods. These rocks remained in the same location after they were retrieved from neighbouring islands – it was just the ownership of them that was exchanged. One of these rai stones even sunk in a canoe during transportation, but rather than the owner losing their 'money', it was accepted that the rai was on the seabed now. It had the same intrinsic value and was still exchanged.

But it's not all obscure – albeit interesting – entries. Oliver talks about the life and death of Jesus Christ, football through the ages, the sacking of Lindisfarne by the Vikings, Tycho Brahe and his metal nose and more. But even in these better known stories of the making of the world as we know it today, there are poignant insights and fine details that will engage the most learned reader.

"It's made up of key points in history that we either had no knowledge of, or the very briefest acquaintance with"

It's a weighty book, and definitely not one for younger **How It Works** readers, but anyone with a passing interest in history will find *The Story of the World in 100 Moments* hard to put down.



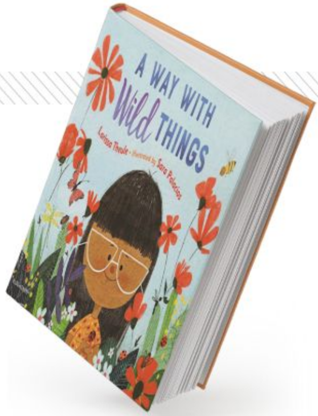
DINOSAURS: NEW VISIONS OF A LOST WORLD

WHAT THEY REALLY LOOKED LIKE

AUTHOR **MICHAEL J. BENTON**
ILLUSTRATOR **BOB NICHOLLS**
PUBLISHER **THAMES AND HUDSON LTD**
PRICE **£25.00 / $39.95**
RELEASE **OUT NOW**

World-leading palaeontologist Michael J. Benton cracks open the fossil evidence to reveal the truth behind what dinosaurs looked like in this fascinating and remarkably illustrated guide. Benton breaks down the science behind the appearance of dinosaurs and whether they had feathers, fur or scales. Taking 15 examples of animals long lost from Earth, Benton takes an intricate look at the methods scientists have used to decode the history of dinosaurs, while Nicholls has produced terrifically detailed illustrations with that information. Not only can the reader expect to discover some surprising changes in their perspective of dinosaurs, but are guaranteed to be introduced to new species entirely. Overall, this is a fascinating read for any natural history enthusiast, although it is clearly written with a more adult analytic brain in mind.

A WAY WITH WILD THINGS



THE STORY OF A SHY NATURE LOVER

AUTHOR **LARISSA THEULE**
PUBLISHER **BLOOMSBURY CHILDREN'S**
PRICE **£6.99/ $15.14**
RELEASE **OUT NOW**

Poppy Fields shares a deep connection with the natural world. She spends her days among the wildflowers and likes to chat with animals more than people. Nature is in her name, and constantly on her mind, but this is the story of how it can also bring her confidence when she needs it most. This delightful picture book is filled with vibrant illustrations, teeming with entertaining details for young children to absorb. As you turn each page, there is a new opportunity to spot the main character hiding in every scene. The rhythmical and engaging text guides the reader through the thoughts and feelings of an introverted child as she makes a

AMELIA EARHART

HER LIFE IN PICTURES

AUTHOR **INSPIRED INNER GENIUS**
PUBLISHER **IIG PUB**
PRICE **£9.99 (APPROX. 13.85)**
RELEASE **OUT NOW**

History's most influential characters have the power to inspire both adults and children alike, and this book by Inspired Inner Genius makes Amelia Earhart's life story accessible to young readers. Divided into 12 large illustrations, the most pivotal moments in the aviator's life are described in concise and captivating text.

The main character in this book teaches care and compassion, bravery and independence, but what makes the cartoon superhero even cooler is that she was real. From record-setting flights to her dramatic disappearance, her story is full of surprises from start to finish. This version of Amelia Earhart's life has the capability to inspire all young readers to follow their dreams and push the limits.

"What makes the cartoon superhero even cooler is that she was real"

INSIDE ANIMALS

PEER INSIDE THE BODIES OF ANIMALS FROM AROUND THE WORLD

AUTHOR **BARBARA TAYLOR**
ILLUSTRATOR **MARGAUX CARPENTIER**
PUBLISHER **WIDE EYED EDITIONS**
PRICE **£14.99 / $15.95**
RELEASE **OUT NOW**

Readers can work their way through the bodies of more than 20 different animals – and discover many fascinating facts and amazing anatomy along the way – with this illustrative guide. Although this book is jam-packed with fun animal insights and surprising facts, the vibrant, cartoonish illustrations are easily the best part of the book.

From recognisable organs such as the heart, lungs and intestines to strange internal structures such as spider silk glands, jellyfish stingers and the segmented heart of scorpions, this book is filled with 21 anatomical cross-sections to enjoy. Carpentier's colour-block illustrative style is a perfectly appropriate accompaniment to a children's book about animal anatomy: no traumatising images of vivisection, it's just blobs and shapes in bright colours.

This is a wild read that would make a great non-fiction bedtime story alternative, or if you've got a budding animal biologist at home, it will make a great introduction to what's beneath the feathers, fur and scales of animals from around the world.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

5			7					
	3		6			9	4	
						5	7	2
1	5		9	3		2		
3				1				4
		9		7	6		5	3
9	4	1						
	2	5			7		8	
					2			6

MEDIUM

	7						2	9
	6	5			2			
		8	6	4		3		
5	4					1		
6			1	7	5			8
		1					3	5
		4		8	6	9		
			4			8	6	
8	9						7	

HARD

3				6		5		
6	1	9	5					
	8		9		3			
4	3			7	8			
	2						3	
			2	3			8	5
			3		9		5	
					4	9	1	3
		3		8				4

Word search

Find the following words

EARTH
CORE
FLIP
TOOTH
UTAH
SURVIVE
CARBON
BLACK
SCROLL
ANCESTOR
NUCLEAR
FIRE

A	Y	T	O	O	B	E	Y	B	L	A	C	K	U	Z
F	O	E	N	L	A	K	G	H	N	U	N	O	L	L
L	T	E	A	R	T	H	C	R	A	B	U	T	A	N
O	W	N	E	C	O	Y	I	P	N	F	C	J	E	R
N	U	T	E	M	O	R	T	I	C	O	H	U	F	P
O	E	H	C	F	T	L	A	K	E	Y	O	R	I	N
B	E	M	O	N	H	F	V	E	S	B	I	L	R	O
R	A	S	R	D	O	R	B	E	T	N	F	S	E	R
A	P	N	E	I	A	Y	L	A	O	Y	R	B	L	A
C	K	E	A	E	N	T	D	H	R	A	V	C	E	M
T	O	M	L	N	A	R	Y	A	F	G	K	H	J	O
N	U	C	K	R	O	B	I	T	E	A	T	U	P	E
I	U	X	T	A	D	E	S	U	J	E	R	B	E	T
N	S	U	R	V	I	V	E	F	I	N	A	C	O	D
D	Y	E	M	O	N	T	C	L	L	L	O	R	C	S

What is it?

Hint: You might spot one of these ready to unfurl in the woods...

A

Spot the difference

See if you can find all six changes between the images below

Answers

Find the solutions to last issue's puzzle pages

Q1 CHARLES BABBAGE
Q2 IT VIBRATES WATER
Q3 JAMES WEBB
Q4 BRAIN
Q5 A COMPUTER
Q6 AN EXTINCT OX

What is it?

A COMPUTER CHIP

Spot the difference

QUICKFIRE QUESTIONS

Q1 What type of plant do bananas grow from?
- Tree
- Herb
- Shrub
- Bush

Q2 How many craters have been officially recognised on the Moon?
- 298
- 809
- 2,240
- 9,137

Q3 What were the warriors of feudal Japan known as?
- Otaku
- Gaijin
- Samurai
- Bushido

Q4 Haemoglobin is found in:
- White blood cells
- Red blood cells
- Liver cells
- Skin cells

Q5 The Great Basin bristlecone pine tree can live to over:
- 1,000 years
- 3,000 years
- 5,000 years
- 9,000 years

Q6 In personal computing, what does RAM stand for?
- Rapid Access Memory
- Random Access Map
- Rapid Area Memory
- Random Access Memory

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HOW TO...

Practical projects to try at home

MAKE A BUG CATCHER

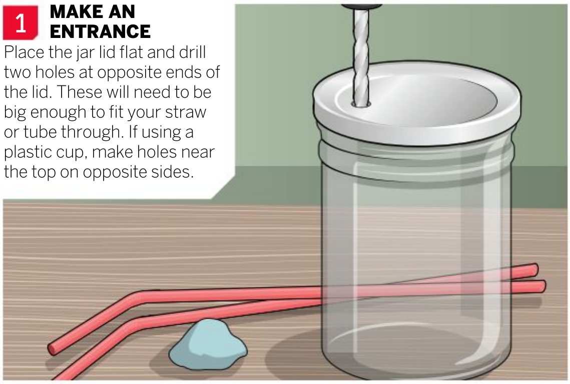
Use this tool to suck garden critters up and observe them closely

KIT LIST

- A screw-lid glass jar or clear plastic pot
- Two bendy straws or thin plastic tubes
- Small piece of muslin or old tights
- Blue tack
- Hammer and nail or a drill
- Scissors
- Sellotape

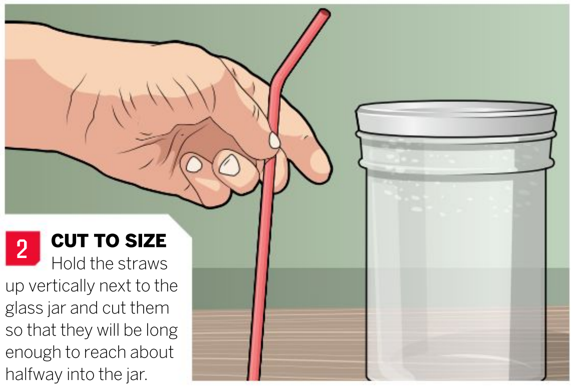
1 MAKE AN ENTRANCE

Place the jar lid flat and drill two holes at opposite ends of the lid. These will need to be big enough to fit your straw or tube through. If using a plastic cup, make holes near the top on opposite sides.



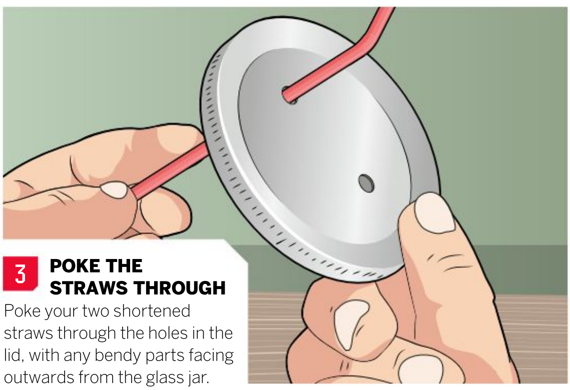
2 CUT TO SIZE

Hold the straws up vertically next to the glass jar and cut them so that they will be long enough to reach about halfway into the jar.



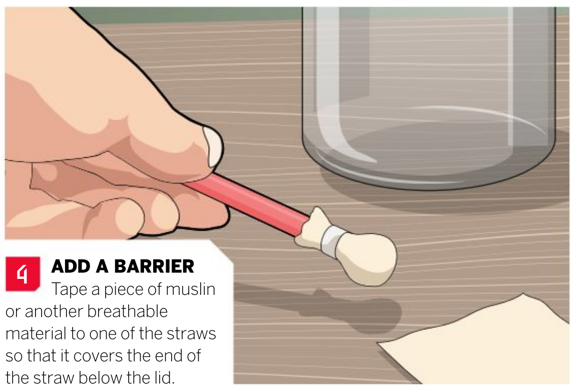
3 POKE THE STRAWS THROUGH

Poke your two shortened straws through the holes in the lid, with any bendy parts facing outwards from the glass jar.



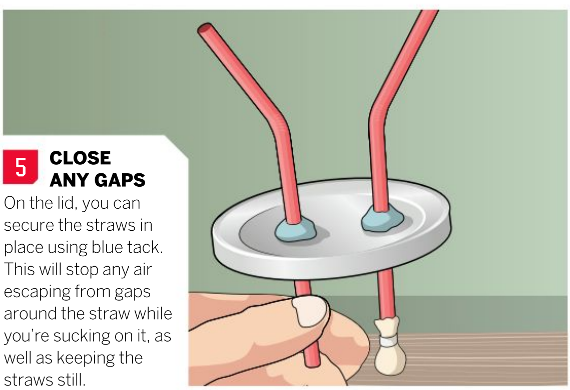
4 ADD A BARRIER

Tape a piece of muslin or another breathable material to one of the straws so that it covers the end of the straw below the lid.



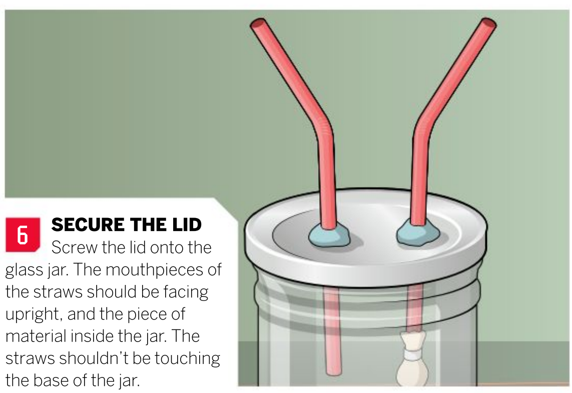
5 CLOSE ANY GAPS

On the lid, you can secure the straws in place using blue tack. This will stop any air escaping from gaps around the straw while you're sucking on it, as well as keeping the straws still.



6 SECURE THE LID

Screw the lid onto the glass jar. The mouthpieces of the straws should be facing upright, and the piece of material inside the jar. The straws shouldn't be touching the base of the jar.



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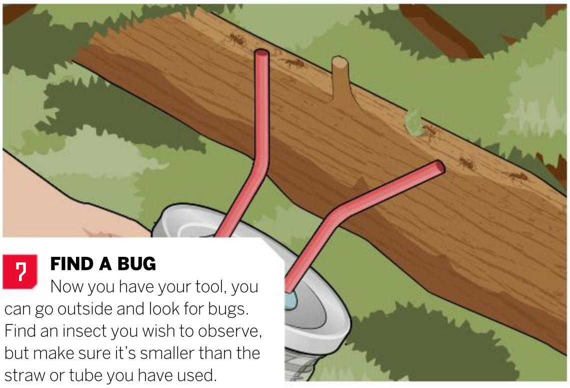
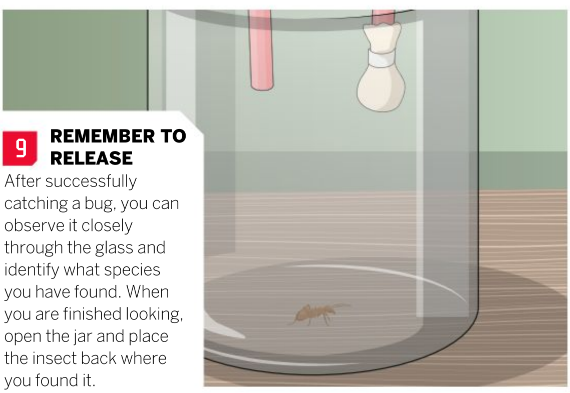
NEXT ISSUE
HOW TO TURN GLASS INVISIBLE

DON'T DO IT ALONE!
If you're under 16, make sure you have an adult with you



7 FIND A BUG
Now you have your tool, you can go outside and look for bugs. Find an insect you wish to observe, but make sure it's smaller than the straw or tube you have used.

8 SUCK IT UP
Take the straw that has the mesh on the other end and put it in your mouth. Then, holding the jar still, position the other straw's opening close to the bug. Gently suck the straw until there's enough force to lift the bug into the jar.



9 REMEMBER TO RELEASE
After successfully catching a bug, you can observe it closely through the glass and identify what species you have found. When you are finished looking, open the jar and place the insect back where you found it.

SUMMARY

The technical name for this simple bug-trapping device is a 'pooter'. Entomologists are scientists who study insects, and they often use tools like this to survey the species found in a particular area. It's a popular choice because insects can be transported into a contained space without being harmed or handled.

The capture works using suction. As you remove the air in the jar by sucking, air from the outside is forced into the jar through the opening of the other straw. Because you've placed the end near the insect you're trying to catch, the light insect gets swept up into the straw by the displaced air. If you use too much force while sucking up insects, you might end up transporting them along two straws and towards your mouth. This is why the material is placed on one end, preventing you from getting a mouthful of bugs! To remember which straw to suck, you can mark one straw with tape or a pen to stop you having to check the end each time. For catching bigger bugs, use wider tubes as opposed to thin straws.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX

Speak your mind

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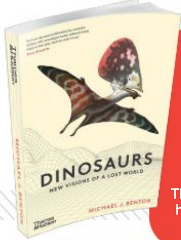


WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH!

THE DINOSAURS: NEW VISIONS OF A LOST WORLD

This visually stunning guide goes beyond the headlines to bring long-extinct creatures to life, with insights into their behaviour, adaptations and appearance using the latest science and cutting-edge research.

UNDER THE MICROSCOPE

Dear **HIW**,
My son, who just finished year seven, took part in his school STEM club. This term they looked at DNA, and he took a rather good photo of the DNA of a banana. It was included in his school newsletter. We are rather proud of it, so I wanted to send it to a couple of science magazines to see if anyone would like to comment!
Julia Higgins


This DNA was extracted from a banana and viewed under a microscope

LETTER of the MONTH

What a great image! Being able to see DNA in such definitive strands closes the gap between us and such a miniscule structure. It looks like you've managed to extract this banana DNA and focus your microscope on chromatin fibres. The strands you can see twisting around the plate are densely packed with DNA as molecules have coiled together. You are right in that this is an image to be proud of, and we hope it can inspire your son to see what else he can uncover in the world of STEM.

DOXFORD'S ENGINES

Dear **HIW**,
I've just picked up your magazine and read with great interest the article about the Wärtsilä engine. I served my apprenticeship building a smaller English version of this type of engine, and have never been able to work out why they went out of fashion some 60-odd years ago.

The engine was the Doxford, which came in three, four and six cylinders and featured two opposed pistons in each cylinder. While they were complicated, their operating principle was simple because there were no valves to worry about, and being crosshead engines they ran forever and a day with minimal wear, but with regular maintenance. There were several similar engines built by different shipbuilders, but Doxford and Burmeister & Wain were the main types.
Ian Johnson

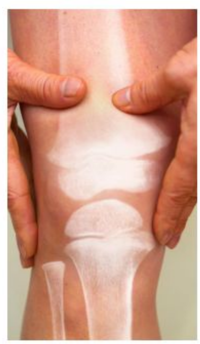
It's fascinating to hear your thoughts on the Doxford engine and how it compares. During the 1960s, Doxford engine sales began to decline, and the last one was built in 1980. Some of the factors contributing to this include some crankshaft failures and being late to incorporate turbocharging, combined with the general decline of British shipbuilding industries.


A Doxford 67 LBD4 engine

TRUTH OR MYTH?

Dear **HIW**,
Is there any truth in the tale that lying or sleeping on damp ground will give you rheumatism? And if so, why? I don't believe there is, because I have spent a lot of time doing this with no ill effects!
Stephen Conn

The idea that dampness can impact your joints largely comes from some arthritis sufferers noticing changes in their condition matching the weather. However, there is no scientific evidence to confidently link joint pain and dampness. This would be unlikely due to the nature of your skin. Your skin serves as a barrier between joints and the damp ground, preventing moisture from having an impact. Other elements of damp weather, such as changes in air pressure, could be the culprit of some people's increased pain, as this can create inflammation.


Cold weather can worsen joint pain

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Artemis astronauts will further explore the lunar surface

MOON MOTIVES

Dear **HIW**,
Why do we want to return to the Moon?
Rhys Jones

It may seem like a repeat achievement since the success of the Apollo missions, but the next trip to the Moon has different goals. Previous trips were focused almost solely on making it to the Moon, but the Artemis missions will explore what we can do while we're there. Scheduled for 2024, the Moon landing will focus on long-term presence. Compared to the Apollo astronauts' three days on the Moon, Artemis astronauts will try to create a base there, which will allow them to stay for months at a time.

Not all lab jobs require a degree

CAREERS IN SCIENCE

Dear **HIW**,
How can you get into natural sciences without a degree?
Ellie Meredith

Some employers have apprenticeship schemes available which provide you with scientific training without needing a degree. Others enter science research roles by starting out as a lab assistant. Many science careers take place outside of research and development. With the appropriate job experience or training, it's possible to work for scientific companies in other areas, from being on their sales team, writing content or working as a technician.

WE ASKED YOU

This month on social media we asked you: "Do you believe there is intelligent life beyond Earth?" 86 per cent of followers voted yes, with just 14 per cent voting no

@SUSYVIEITES
Yes, got to be something better than us humans!

@MARIA GEORGIOU
Yes! That's why we can't find them. They are hiding from us

@SAMMY.GLANFIELD
In a universe like ours, it seems unlikely that only one planet contains intelligent life

@LEFTERHHS_STAV
Yes. There is life because the universe is endless

@AARASH_GHP
Yes. Think about how enormous the world is and possibilities

@JO COLLINS
Half the time I wonder if there is intelligent life on Earth

@KHALILLDOUADI
No. If yes, we would be at war right now

@MARK BRADLEY
Got to be more intelligent than most of the people on the Earth

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FAST FACTS

Amazing trivia that will blow your mind

125 BILLION MILES

If your DNA was laid out end to end, it would stretch from the Sun to Pluto and back 17 times

100 MILLION MEGATONNES

A solar flare can release energy equivalent to 2 million of the world's biggest nuke

100 MICRONS

The world's smallest fidget spinner is smaller than the width of a human hair

2,000

Every minute, there are thousands of thunderstorms on Earth

A KILLER WHALE IS TECHNICALLY A DOLPHIN

80%

Sloths and armadillos spend four-fifths of their day sleeping

116.07 METRES

The world's tallest tree is a redwood in California called Hyperion

1947

The first animals sent into space were fruit flies

YOU CAN'T TASTE FOOD WITHOUT SALIVA

Your body contains ten times more bacterial cells than human cells

30,000 DEGREES CELSIUS

A bolt of lightning can be five times hotter than the surface of the Sun

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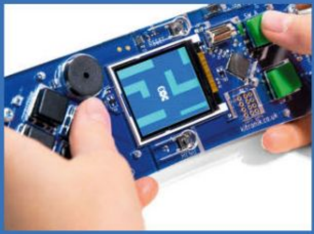

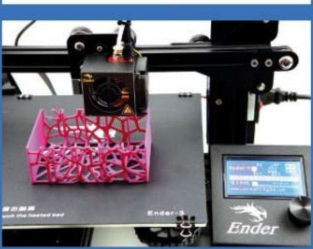

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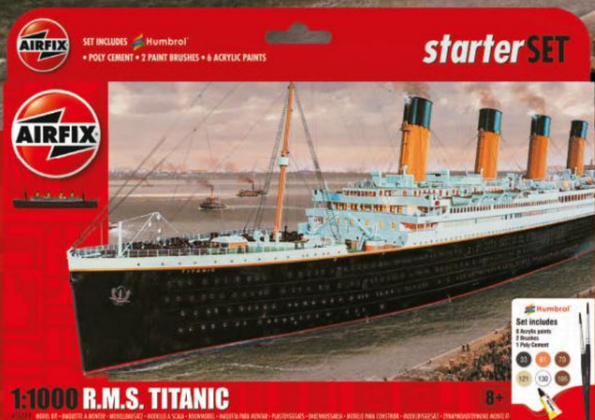

The RMS Titanic will go down in maritime history as not just the largest and most luxurious passenger ship afloat upon its launch in 1912, but also as the most infamous, due to its now legendary maiden voyage. Despite warnings given to it by other ships, the Titanic steamed into the side of an iceberg on the night of the 14th April 1912. This tore a large hole in the side of the hull, overwhelming the ship's famed, watertight compartments. As water poured in, the order was given to abandon ship, with women and children being prioritised over the men. Of the 2224 passengers on board, just 711 survived, with the vast majority being women and children of the first and second class. Today, more than 100 years after its maiden voyage and sinking, the legend of the Titanic continues to capture the imagination of the world.

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